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The Tenth International Astronautical Conference

The Tenth Congress of the International Astronautical Federation was an unqualified success and will long be remembered by those who attended it.

The principal feature of these congresses is undoubtedly the technical sessions. So many papers were presented at Church House that it would be unfair to single out one or two for comment. The average standard of the contributions was higher than in previous years, owing to the more stringent selection policy adopted by the screening committees. The number of participants exceeded previous records and the Society's expectations, but although the band of voluntary helpers who acted as registration clerks, cashiers, stewards, etc., were very hard pressed at times, they were always able to master their difficulties.

All the social activities were popular, and they provided an excellent opportunity of meeting well-known astronautical personalities from oversea. This opportunity was not restricted to the functions listed on the printed programme—thus, after the Government reception at Lancaster House, a large group, including B.I.S. members, several American delegates and a couple of Russians adjourned to a riverside inn at Wapping to continue getting acquainted with one another.

The main decisions taken at the business sessions were that an Academy of Astronautics and an International Institute of Space Law should be established, although the details of the organization of these bodies still remain to be settled and will receive further consideration at the Stockholm Congress in 1960.

The London Congress represents a considerable achievement for the Society. Mention was made above of the Government reception, at which the participants were welcomed by the Minister of Supply, Mr. Aubrey Jones. The Minister also attended the inaugural session of the Congress and opened it officially, emphasizing in a few well-chosen words how necessary it was for the state to undertake research in astronautics. Mr. Jones has since left politics to return to industry and our best wishes go with him. We also hope that his successor—the Rt. Hon. Duncan Sandys, Minister of Aviation—shares his progressive views on this subject.

To some extent the Congress overshadowed the meeting which immediately preceded it—the Commonwealth Spaceflight Symposium. Nevertheless, the effects of the Symposium will be long-lasting. It provided a forum for the presentation of ideas on the action to be taken in establishing a British spaceflight programme, and interesting projects for satellites were advanced by the staff of the de Havilland Propeller Company and the Hawker Siddeley Group. The Council does not intend to let matters rest there; plans are already being drawn up for the Second Commonwealth Spaceflight Symposium and for various other activities which are a logical outcome of the First Symposium. These will be announced in due course.

G. V. E. THOMPSON.

A NOVEL SYSTEM FOR SPACE FLIGHT USING A PROPULSIVE FLUID ACCUMULATOR*

By STERGE T. DEMETRIADES,† A.B., M.S., Mech.Eng.

ABSTRACT

A novel propulsion system for spaceflight is described which, by collecting and storing gases in the upper atmosphere of a planet and by using these gases as a propulsive fluid (in conjunction with a power source), can bring about significant decreases in the required take-off mass.

I. INTRODUCTION

ALTHOUGH it has been recognized for some time that great economies can be effected in space travel by splitting the problem into two distinct phases, the booster phase (concerned mainly with escape from the Earth's gravitational field) and the sustainer phase (concerned with providing low thrust at very high specific impulse for long periods of time), the devices proposed for solving the second phase of the problem (ion rockets, colloid rockets, plasma jets, etc., deriving energy from a nuclear reactor) still suffer from the disadvantage that the greater part of the weight of the space vehicle must be made up of propulsive fluid.‡ Since with present techniques it takes scores of pounds of propellent and power plant to put one pound into orbit, even greater economies can result if the mass of propulsive fluid required for spaceflight can be eliminated from the total take-off mass.

The essential feature of this scheme is to lift only the energy source into orbit at approximately 100 km., and at that point to collect the propulsive fluid for continuing the journey into space. This is accomplished by a Propulsive Fluid Accumulator, or PROFAC, and some figures presented here (Fig. 1, 2, 3) reveal the startling reduction in take-off mass made possible by this approach. Without going into too much detail it will suffice to point out that the energy required to scoop, liquefy and store one pound of air at orbital speeds is ten to one hundred times less than the energy required to lift one pound of mass into orbit with present techniques.

The principles involved in the operation of the Propulsive Fluid Accumulator are not different from those involved in a two-phase wind tunnel, at least one of which is now operating.

The development of the PROFAC device is the logical extension of the work the author has been doing in upper planetary atmosphere power plants.[1] The success of this device would have such immediate and beneficial impact on the economics and potentialities of space travel that we may refer to it as the PROFAC system for spaceflight, even though we recognize that the PROFAC is only a component part of the system.

1. THE UPPER ATMOSPHERE AS A SOURCE OF PROPULSIVE FLUID

The upper atmosphere serves as a gigantic storage tank for a useful propulsive fluid—air. At 100 km. altitude, the density of the atmosphere is approximately $7{\cdot}1 \times 10^{-10}$ g./cm.^{3} (Fig. 1), and it consists of a mixture of oxygen atoms and oxygen and nitrogen molecules.

One possible way of using this gaseous mixture would be as a monopropellent. At that altitude the dissociated oxygen atoms can supply approximately 20 ergs./cm.^{3} by recombination. But the atoms cannot be stored in a

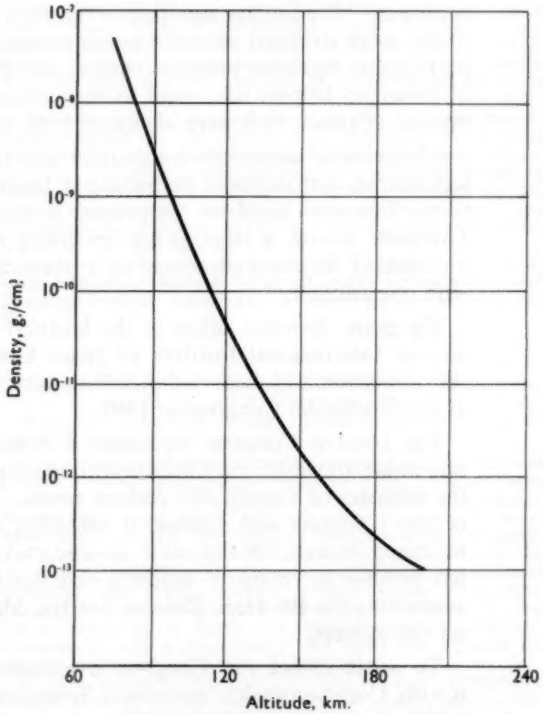

FIG. 1. Density of upper atmosphere, ARDC Model, 1956.

* Manuscript received 3 January, 1959.

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‡ Propulsive fluid or expellent or working fluid or reaction mass is the mass that must be ejected to provide thrust. These terms are used to signify that this mass does not contain the energy required for its own acceleration. When it contains that energy the correct term is propellent.

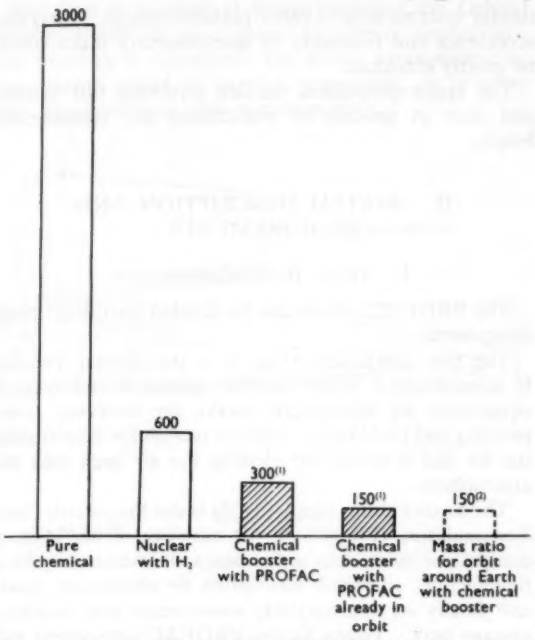

FIG. 2. Relative mass ratios required to land one pound of payload on the Moon on equivalent basis[3].

(1) Includes return trip to Earth.
(2) Given for reference.
(3) Assumes 150 lb. are required to put 1 lb. in orbit round the Earth.

high-energy state, and could be used as a propellent only to maintain orbital speeds while collecting the balance of the air. Even in this case, calculations have shown[1,2] that the energy of recombination is not alone sufficient to counteract the aerodynamic drag on the vehicle at orbital speeds (at the same time, the air is too thin to provide useful lift at suborbital speeds).

The gas mixture has great value, however, as a propulsive fluid. The density may be low, but it is far from zero, and any vehicle circling the Earth at orbital speeds would cut a "doughnut" path containing a surprising weight of gaseous matter. At 100 km. approximately 400 kg. of air can be collected in one day by a 1 m.^{2} scoop.

2. Putting the Air to Work

There are two basic ways in which the thin gases of the upper atmosphere could be put to work. The first would be to power an Orbital Vehicle in conjunction with a nuclear energy source. The objective would be to provide sufficient thrust to counteract the low aerodynamic drag encountered at this altitude. In this case, the vehicle would consist simply of a method to collect the air, accelerate it and project it to the rear, *i.e.*, an orbital ramjet.

Since only a slight thrust would be needed, a low-power nuclear reactor would serve as a suitable power-plant for a low-altitude satellite of almost indefinite life. Since the vehicle would be developing thrust, it would also be manœuverable, and this, in itself, would be of sufficient advantage to warrant interest.

The second, and most important use of the air would be as a propulsive fluid for a true Space Vehicle. Before the air could be used in this fashion, it would have to be collected and stored, and the principal role of the powered satellite would be as a fluid collector. The orbiting powered satellite or excraft* would carry with it a PROFAC unit to collect and store air to be used for space travel by a second vehicle. Here the stored air would be used as a reaction mass (in the form of molecules, atoms or ions or a plasma) to propel the space vehicle on its mission.

In early experiments, the Space Vehicle, PROFAC, and Orbital Vehicle would probably be combined into a single package during the launching phase. The Orbital Vehicle and PROFAC would be detached after sufficient air had been collected. In later versions, however, the Orbital Vehicle and PROFAC unit would be a permanent "fueling station" in the sky, with which space vehicles would make rendezvous on their trip away from the Earth. Similar powered stations could be established in other planets or their satellites.

3. Reduced Take-Off Mass

A simple comparison will illustrate the great advantages that would result from this scheme. To land a one-pound payload on the Moon with a multistage chemical

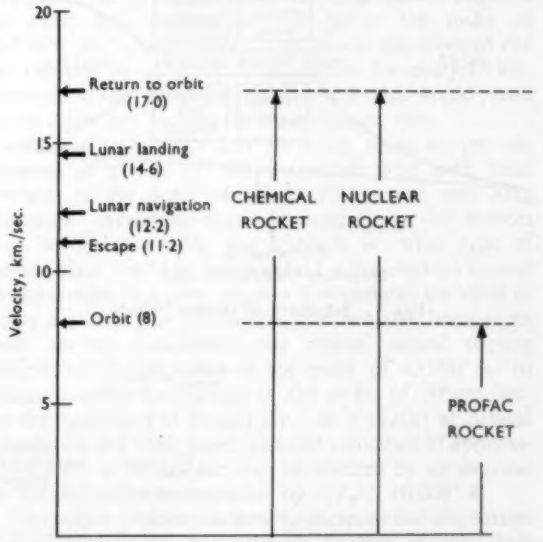

FIG. 3. Relative velocities that must be achieved with take-off mass for different systems in order to land on Moon and return.

*See Reference 2 for definition of *excraft*.

rocket requires approximately 3,000 lb. of take-off mass (assuming no return to orbit around the Earth). A multistage nuclear rocket with hydrogen as a propulsive fluid (if one could be developed) would require approximately 600 lb. of take-off mass to accomplish the same objective.

The PROFAC scheme, on the other hand, would require only 300 lb. of take-off mass per pound of payload for the entire trip to the Moon and return. And this would apply only to the first trip. If the PROFAC equipment were left in orbit around the Earth, subsequent trips to the Moon and back would require only 150 lb. of take-off mass (Fig. 2 and 3).

The important saving in subsequent trips is of extreme significance. With PROFAC equipment in orbit, the only expense of putting pay-loads into lunar or interplanetary trajectories is that involved in lifting them the first few score miles and into orbit. In other words, the chemical-rocket mass requirement for low-altitude orbit is all the reaction mass that is required for subsequent travel in space.

At the same time, an orbiting, powered PROFAC fueling station would be a device of great potential military significance. In effect, the PROFAC scheme offers a practical solution to both the Orbital-Strategic and Lunar-Strategic vehicle problems. By establishing similar systems around other planets (notably Mars) the economics and feasibility of interplanetary flight could be greatly enhanced.

The space propulsion studies involving this system and now in process of publication are summarized below.

II. SYSTEM DESCRIPTION AND REQUIREMENTS

1. Three Basic Components

The PROFAC system can be divided into three basic components.

The first component (Fig. 4) is the Orbital Vehicle. It consists of a power source, guidance and control equipment, an appropriate intake for receiving, compressing and ionizing air, a driver section for accelerating the air and a nozzle for ejecting the air back into the atmosphere.

The second component (Fig. 5) is the Propulsive Fluid Accumulator, (PROFAC). It consists of an inlet, a compressor subsystem, a fixation unit (which may be a liquefaction, chemical, adsorption or absorption plant) and finally an appropriately constructed and insulated storage tank. Power for the PROFAC component will normally come from the Orbital Vehicle power source.

The third component is the Space Vehicle (Fig. 6). This contains guidance and control equipment for space navigation and a number of power plants or stages appropriate to its mission.

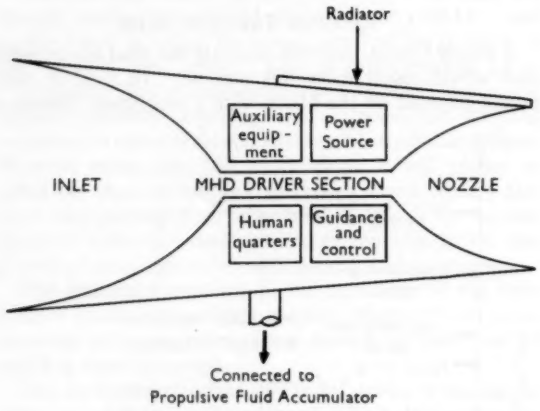

FIG. 4. Schematic of Orbital Vehicle.

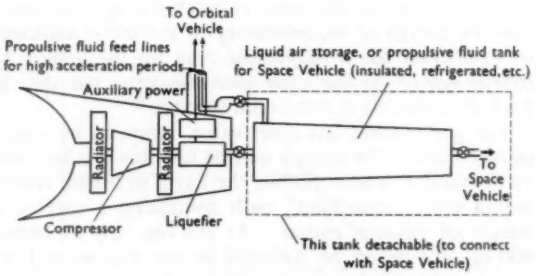
To Orbital Vehicle
Propulsive fluid feed lines for high acceleration periods
Liquid air storage, or propulsive fluid tank for Space Vehicle (insulated, refrigerated, etc.)
Auxiliary power
Radiator
Radiator
To Space Vehicle
Compressor
Liquefier
This tank detachable (to connect with Space Vehicle)

FIG. 5. Schematic of Propulsive Fluid Accumulator (PROFAC).

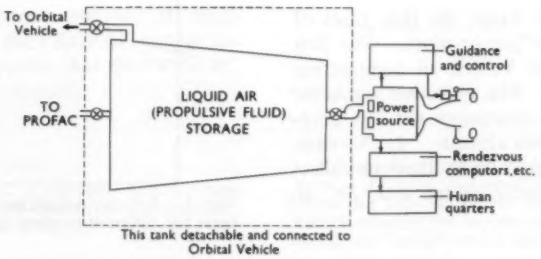

FIG. 6. Schematic of Space Vehicle (one stage shown only, many can be connected)

Fig. 7 is a conceptual design showing the Orbital Vehicle, PROFAC and Space Vehicle in rendezvous. The drawing is schematic; the actual arrangement of components would be parallel, concentric, or in some other compact form with minimum drag.

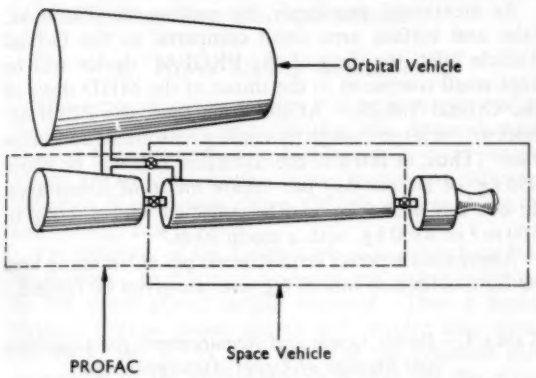

FIG. 7. Schematic of Orbital Vehicle, PROFAC and Space Vehicle in orbit rendezvous.

2. System Requirements

The design requirements for the successful operation of a PROFAC system would consist of:

(1) A means to counteract the aerodynamic drag of the Orbital Vehicle and PROFAC plant while collecting air.

(2) A means for collecting and storing air at 100 km. and orbital speeds.

(3) Power sources having high energy content per unit weight, long life and moderate power output.

(4) A means for producing thrust for Space Vehicle propulsion.

(5) Guidance and navigation equipment required to rendezvous the Orbital and Space Vehicles and to execute various missions.

A discussion of each of these requirements follows. It should be noted that none of these requirements are beyond present technology, although experimental work would be required to prove their operational characteristics. The total weight of all three components need not exceed 10 to 50 tons.

3. Producing Thrust for Propulsion of the Orbital Vehicle

The first requirement for a permanent, powered satellite at an altitude between 85 and 120 km. is a method of producing enough thrust to overcome drag.

The maximum drag of a vehicle flying at orbital speeds at 100 km. is of the order of 6 dynes/cm.^{2} of skin surface.[1,2,3] For a vehicle with an inlet of 1 m.^{2} and 5 m. long, the skin friction drag is less than $1{\cdot}2 \times 10^6$ dynes. If all the air through the inlet is stopped relative to this orbiting vehicle, the additional drag is $4{\cdot}5 \times 10^6$ dynes. Extreme care must be exercised in handling the hypersonic (Mach No. $\cong 25$) low-density air stream.

If, however, only one-fiftieth of the entering air is stopped and collected, the drag due to collection will be approximately $0{\cdot}1 \times 10^6$ dynes. Since the Orbital Vehicle can be designed so that the cross-sectional area of the inlet is equal to the frontal area of the vehicle and the PROFAC scoop can be designed so that its area is a fraction, say one-fiftieth, of the Orbital Vehicle inlet area, the total drag of the Orbital Vehicle, including PROFAC equipment, will be less than $1{\cdot}3 \times 10^6$ dynes (wave drag is negligible at this altitude[1,2,3] and PROFAC skin-friction drag can be neglected since the PROFAC surface area can be made negligible compared to the Orbital Vehicle surface area).

Since the mass rate of flow through 1 m.^{2} is about 6 g./sec., the exhaust velocity, V_4, required will be given by $V_4 = (1{\cdot}3 \times 10^6)/6 + V_1 = 2{\cdot}2 \times 10^5 + V_1$ cm./sec. With the orbital speed, $V_1 = 8 \times 10^5$ cm./sec., it follows that $V_4 \cong 1{\cdot}28\, V_1$. Actually, it may be shown that this is a high estimate for the drag[2,3] and that by appropriately shaping the external walls (*i.e.*, converging them towards the rear) the total drag, including wave drag and diffuser losses, may be halved, so that for the ratio length/diameter $= 5$, the exit velocity required to overcome the total drag is $V_4 \geqslant 1{\cdot}15\, V_1$.

It is significant that the required velocity increment is relatively small. Since only small mass rates of flow (10 g.sec.$^{-1}$m.$^{-2}$) are involved, the total power required to effect this acceleration will be of the order of 0·4 MW./m.^{2} of inlet area. This power requirement can be reduced by an order of magnitude for every 15 km. increase in operating altitude, although this would result in an attendant decrease in the collection rate.

Nuclear technology can be relied upon to provide sources of power of this magnitude and with total weights of the order of 10^3 to 10^4 kg. and very long lifetimes. Assuming that such long-life power sources will become available, the question is: what type of power plant would be most useful? The obvious answer is the ramjet, not only because it eliminates the need to carry a working or propulsive fluid but also because its only serious competitor, the rocket, would require stagnation temperatures of the order of 45,000° K. to produce exhaust velocities of the order of 10^6 cm./sec. by the expansion of heated air. In a ramjet at orbital speeds, on the other hand, exhaust velocities of approximately $9{\cdot}5 \times 10^5$ cm./sec. can be reached by an increase of the stagnation temperature by $\triangle T_0 \cong 10{,}000°$ K.

The major problem is how to increase the stagnation temperature of the gas. Simple heating at these low densities and high temperatures can be ruled out. One method for accelerating low-density, high-speed flows (other alternative methods are also under consideration) consists of an electrical discharge, with or without

electrodes, followed by magnetohydrodynamic (MHD) acceleration consisting of crossed applied electric and magnetic fields. It should be emphasized that the acceleration of low-density high-speed flows does not now involve a question of efficiency but rather of method, *i.e.*, at this stage any method that will do it deserves consideration.

The theory of simple, constant-area MHD acceleration of supersonic flows of partially ionized gases is relatively well understood.[4] Theoretical computations indicate that if the conductivity of the inlet air is raised to 10 mhos/cm., the ratio $V_4/V_1 = 1{\cdot}50$ may be obtained with a magnetic field of 100 gauss, and an electric field of 2·7 volts/cm. acting across a channel of 100 cm.² cross section (since the inlet area is 10^4 cm.², this implies an area ratio of 100 and a pressure rise by a factor of 1000). The direction of flow is normal to the plane of the mutually perpendicular electric and magnetic fields. The mass flow rate used in this computation was 10 g./sec., the ratio of the specific heats was $\gamma = 1{\cdot}4$, and the initial Mach number (at the entrance of the driver section) was $M_0 = 10$.

The required length of the MHD driver for $V_4/V_1 = 1{\cdot}50$ is of the order of 550 cm. For $V_4/V_1 = 1{\cdot}15$, the length required is only 165 cm. All these computations are based on the work of Resler and Sears.[4] Other MHD driver designs are possible.

It has been verified that there is no electrical breakdown of air under these fields and conditions (*i.e.*, $\rho = 10^{-4}\rho_0$ where ρ_0 is the standard atmospheric density and $P = 10^{-3}P_0$ where P_0 is the standard atmospheric pressure). The conductivity of the air can be increased to 10 mhos/cm. by introducing a virile radioactive coating on the walls of the diffuser followed by an electrodeless (microwave) discharge or a glow discharge upstream of the MHD driver. This discharge will "shake up" the atoms and molecules of the gas and create ion pairs (0·1–1% is sufficient) in much the same way an electrodeless discharge dissociates oxygen and nitrogen.* Ion recombination at these densities is sufficiently slow and the flow velocity is sufficiently high to permit these ions to survive for several metres downstream of the discharge and throughout the length of the MHD driver. Preliminary work carried out indicates that this scheme for raising the conductivity of the air is feasible if the complications introduced by the boundary layer and the applied magnetic field can be overcome. The thermal energy of the stream within the driver is increased only slightly if recombination does not occur.

The MHD drive described here can overcome the drag of the Orbital Vehicle and the PROFAC apparatus and in addition, it can provide positive accelerations of about 10^{-4} *g* for the entire duration of its flight (many months or years). For short periods of high acceleration (up to 5 *g*) the propulsive fluid stored in the PROFAC device or elsewhere in the system, can be ejected in large quantities.

4. Collection and Storage of Upper Atmosphere Air

As mentioned previously, by making the PROFAC inlet and surface area small compared to the Orbital Vehicle inlet, the drag of the PROFAC device will be kept small compared to the thrust of the MHD drive of the Orbital Vehicle. At the same time, the PROFAC inlet will be large enough to insure a reasonable collection rate. Thus, at 100 km. the collection rate will be about 430 kg. of air per day per square metre of scoop area. In one day 43,000 kg. can be collected with a scoop of 100 m.² or 4300 kg. with a scoop 10 m.²

Approximate power requirements per m.² of scoop area or for a collection rate of 6 g./sec. are given in Table I.

Table I.—*Power Levels and Requirements for Collection and Storage of Upper Atmosphere Air*

Process	Power requirement, kW./m.²
Stagnation energy of air and recombination of O atoms	200
Compressor—power to compress from 0·001* to 1 atmosphere and 1000° K.	200
Cooling from 1000° K. to 90° K. followed by liquefaction of air at 1 atmosphere	10
Keeping 100 m.² of surface area (corresponding to 1 m.² of scoop area) cooled against sunlight	100
Losses, pumps, human needs and guidance equipment	490
Total power requirements for collection (6 g./sec. at 100 km.)	1000

* Ram compression accomplishes compression from 10^{-6} to 10^{-3} atmosphere.

These thermal power requirements are order-of-magnitude estimates. They can be reduced by an order of magnitude for a 15 km. increase in altitude, until at about 150 km. the flux of solar energy alone is sufficient to provide power for the Orbital Vehicle thrust engine and for the PROFAC equipment. The attendant decrease in collection rate, however, makes operation at altitudes above 130 km. rather uneconomical from the point of view of time required for collection. It should be noted that 1 MW. of thermal energy can be radiated from a surface of 10 m.² at 1000° C.

Once the air is collected and frozen or liquefied, it will be stored as a liquid in an appropriate tank. The estimated weight of the liquefaction equipment is 150 kg./m.² of scoop area. The estimated weight of the

* An alternative scheme would be to allow a normal shock to form at the inlet. This normal shock at orbital speeds would heat the air to about 5300° K. and cause about 0·1% ionization (at 100 km.) and a conductivity between 5 and 50 mhos/cm.

storage tanks is 5% of the liquid it contains, including insulation and auxiliary equipment.

Low pressure at the end of the inlet will be maintained by liquefaction of the inlet stream, using the same principle as a two-phase wind tunnel. Other methods might be used for the fixation and storage of the inlet stream (*e.g.*, chemical reaction, absorption or adsorption) to decrease further the power requirements.

5. Power Source Requirements

Two types of power sources will be required, one for the Orbital Vehicle and one for the Space Vehicle. Because long life and a very high energy content per unit weight are required, nuclear power sources are indicated, although if operation above 150 km. proves desirable, solar energy can be used.

The difficulty of developing such sources has long been recognized. In this case, however, the task is simplified by the lower power output required. Thus a typical Orbital Vehicle power source will require only about 0·26 MW. per m.^{2} of inlet area for the practical plasmatization of the stream and 0·24 MW. for the actual acceleration of the stream, for operation at about 100 km. altitude.

Assuming that the Orbital Vehicle inlet is 10 m.^{2} this imposes a requirement of 5 MW. The attached PROFAC equipment with scoop area of 1 m.^{2} will require 1 MW. Thus, a total of 6 MW. will be required. Such a power source with auxiliary equipment would weigh about 11 tons with the present state of the art and perhaps as low as 2 tons with the expected development of nuclear power sources in 10 years (using the same dimensions, the PROFAC equipment will accumulate 430 kg. of liquid air per day or 43 tons in 100 days).

The second type of power plant would be specified by the mission required of the Space Vehicle. Assume that its mission is to land 10 tons of payload on the Moon and that the propulsive fluid can be accelerated to about 3×10^5 cm./sec. (by simple heating to about 3000° K.). Then, since the acceleration due to gravity at the surface of the Moon is 163 cm./sec.^{2}, we obtain a required mass-flow rate of $\dot{m}$ from the equation:

$$(10^7 \text{ g.}) \times (163 \text{ cm./sec.}^2) = (\dot{m} \text{ g./sec.}) \times (3 \times 10^5 \text{ cm./sec.})$$

or $\dot{m} \cong 500$ g/sec. Then the power required is approximately $(5 \times 10^3)(9 \times 10^{10})/2 = 2{\cdot}3 \times 10^{14}$ ergs/sec. $= 2{\cdot}3 \times 10^7$ watts $= 23$ MW.

It is clear that the power sources required are small compared to the nuclear rocket power plants now being planned (most are of the order of 10,000 MW.). Consequently the problems should be easier to solve. It must be emphasized that even these power source requirements can be decreased by operating at higher altitudes or using solar energy.

6. Thrust Engine for Space Vehicle

The thrust engine for the Space Vehicle can be a simple boiler-type nuclear engine of about 20 MW. and total mass of about 5 tons, which heats the propulsive fluid by heat transfer and expands it through a nozzle into space for short range (lunar) trips or a more sophisticated plasma or ion-rocket (using N^+ or O^+) for longer range (Mars) interplanetary travel. The problems of both types are well understood and the construction of at least the boiler-type engine presents no new problems since the mass rates of flow are small (5 kg./sec.). Solar energy can be used as the source of power for the space vehicle also. The alternative scheme of carrying the fuel (*e.g.*, hydrogen) to burn with the collected oxygen also deserves attention.

7. Navigation and Guidance Requirements

These requirements are no different than those presently envisioned for space travel. In fact, since both the Orbital Vehicle and the Space Vehicle are under power most of the time, the problem of "mating" may be easier since either one can manoeuver. In any case, the conquest of space will follow the conquest of the upper atmosphere by powered and controlled vehicles.

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GRAPHIC SOLUTION OF SOME EARTH SATELLITE PROBLEMS BY USE OF THE STEREOGRAPHIC NET*

By ROBERT E. WALLACE,† M.S., Ph.D.

ABSTRACT

The stereographic net, which is an equatorial plot of a hemisphere incorporating great and small circle co-ordinates, provides an excellent base for plotting and graphically solving problems of Earth satellite orbits. Plotting of features such as trace of orbit, precession of orbit, pass times, and limits of Earth shadows, permits measurement of relations between different components of the problem as well as aiding visualization of the problem as a whole.

I. INTRODUCTION

MANY problems in spherical trigonometry can be solved quickly by use of the stereographic net. The stereographic projection has long been used in the graphic solution of problems in spherical trigonometry[1,2], yet the simplicity of use of the technique employing a stereographic net apparently is not appreciated by a number of people who have become interested and involved in satellite tracking.

II. STEREOGRAPHIC PROJECTION

The stereographic projection is the plot of a hemisphere, on an equatorial plane as viewed from the pole of the opposite hemisphere. This produces a relationship such that all circular arcs on the hemisphere project as arcs of circles on the plane.

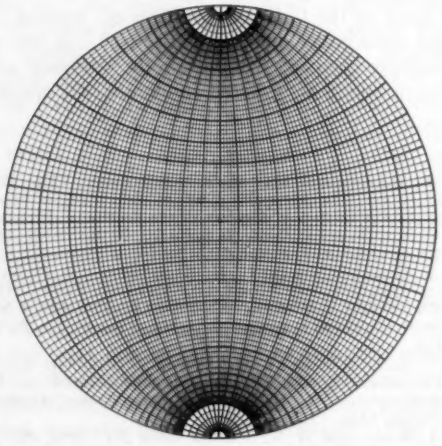

FIG. 1.—Stereographic net divided into great and small circles at 2° intervals. Net 8 in. in diameter with tracing paper overlay is used as instrument for rapid solution of problems in spherical trigonometry. (*Reduced to one-third actual size*).

III. STEREOGRAPHIC NET

A stereographic net is shown in Fig. 1. By way of explanation, this might be thought of as the view of latitude and longitude lines of the western hemisphere of the Earth as seen through the Earth from a point at the intersection of the prime meridian and the equator. The plot of this view is made on the plane that separates the two hemispheres. The latitude and longitude lines of the stereographic net are referred to as small and great circles respectively. The different terminology is desirable because in using the net the great and small circle coordinates generally are at some orientation other than coincident with latitude and longitude lines of the Earth and so a distinction is necessary. Thus in this paper, although the Earth is viewed as looking down on the North Pole, the great and small circle co-ordinates are placed so that the poles of the net through which the great circles pass are on the Equator of the Earth or edge of the net. The net then can be rotated, and the great and small circle co-ordinates can be set at various desired orientations with respect to latitude and longitude co-ordinates.

Just as longitude lines represent the intersection of the spherical surface and planes that pass through the centres of the sphere, so do great circles of the stereographic net. Likewise small circles represent intersections of the surface of the sphere and cones of revolutions about one axis, just as do latitude lines.

Stereographic nets of the Wulff type (Fig. 1) have been in common usage in crystallography and structural geology, and it is this type that has been found useful in plotting satellite orbits. A net 7 or 8 inches in diameter divided into great and small circles at two degree intervals‡ and overlain by a sheet of tracing paper provides the fundamental tool. A simple mechanism can be made by mounting the net on a piece of stiff cardboard and piercing the centre of the net and tracing-paper overlay with a thumbtack or other sharp pivot

* Manuscript received 25 December, 1958.

† 336 Lexington Drive, Menlo Park, California, U.S.A.

‡ Obtainable from E. Leitz (Instruments) Ltd., 20 Mortimer Street, London, W.1, from E. Leitz, Inc., 304 Hudson Street, New York 13, N.Y., U.S.A., or from University of Chicago Bookstore, Chicago 37, Illinois, U.S.A.

point. A precision mechanism for rotating a sheet of tracing paper over the net is produced by E. Leitz, Inc.

IV. PLOTTING AND SOLVING ORBIT PROBLEMS

The following techniques used in plotting orbits of satellites 1957 α and 1957β (*Sputniks* 1 and 2) will serve as examples of the use of the stereographic net.

The centre of the net is considered to be the North Pole (*N*, Fig. 2) and the circumference to be the Equator,

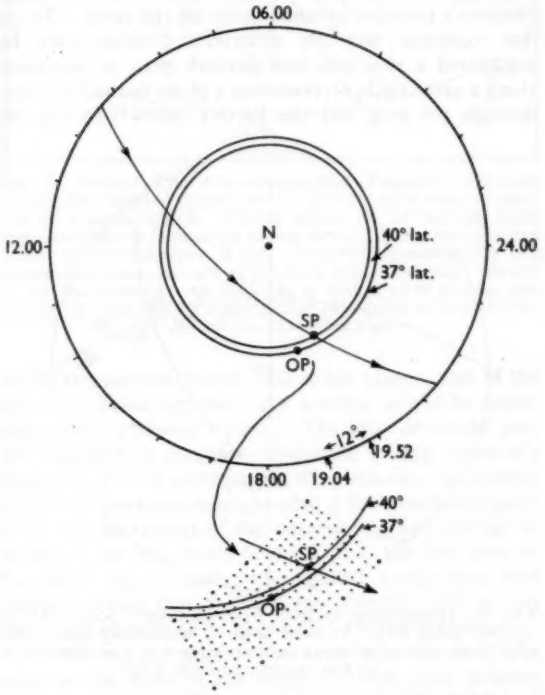

FIG. 2.—Plot of satellite orbit (great circle arc through point *SP*) on a stereographic projection. *SP* is satellite pass over 40° parallel. *OP* is observer's position. *N* is North Pole. Circumference is Equator. Longitude co-ordinates are expressed in time. Detail shows determination of great-circle angle between *OP* and SP accomplished by rotating net until both points lie on same great circle, then reading off small circles between—in this case about 10°.

thus the Earth is pictured as viewed from above the North Pole. A small circle is drawn around the centre of the net to represent the observer's latitude. For the author this is a circle 37° in from the circumference, measured along either of the two straight lines (great circles) passing through the North Pole (*N*). Another circle is drawn to represent the 40° parallel, inasmuch as reporting of the satellites' positions was customarily given as longitude, time, and height of crossing the 40° parallel.

For longitude co-ordinates a time base is employed, and local standard time is plotted around the circumference of the net, allowing 15° for each hour.

The trace of the satellite's orbit for a particular pass and the observer's position are plotted as follows:

Given: Longitude and time of crossing 40° parallel are 110° W. at 03.04 Universal Time or 19.04 Pacific Standard Time. Observer's position is 122° W. and 37° N. Satellite's orbit is inclined at an angle of 65° to Equator.

A point is plotted on the 37°-parallel circle at 19.04. This point (*OP* in Fig. 2) represents the position of the observer when the satellite is crossing the 40° parallel 12° east of him. The point at which the satellite crosses the 40° parallel (*SP* in Fig. 2) is determined by counting 12° (or 48 minutes) counter-clockwise from *OP* and plotting this point on the 40°-parallel circle. Rotate the net under the tracing paper until *SP* lies on the 65° great circle (the great circle 65° in from the circumference of the net). Note that there are two 65° great circles that might be passed through *SP*. The one chosen will depend upon whether the satellite path is oriented north-west/south-east or north-east/south-west. In Fig. 2 the pass is oriented north-west/south-east. Trace the 65° great circle onto the tracing paper overlay; this great circle represents the trace of the satellite's orbit.

To find the great-circle angle between *OP* and *SP*, rotate the net again until the two points lie on the same great circle (see detail in Fig. 2), then read off the number of small circles lying between; in this example about 10°. If the altitude of the satellite also is known, the vertical angle to it can be estimated by referring to a graphic plot such as shown in Fig. 3.

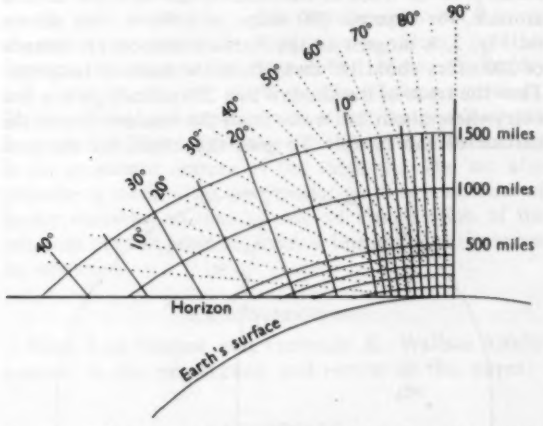

FIG. 3. Grid for graphically relating height, great-circle angle, and vertical angle.

A point on the satellite's orbit of considerable interest in visual tracking is the point at which the satellite passes into or emerges from the Earth's shadow. To determine this, plot the trace of the Earth's shadow at different altitudes as follows. Plot the times of sunrise and sunset on the observer's latitude circle (see Fig. 4), and rotate the net under the tracing paper plot until a great circle passes through these two points. Trace this great

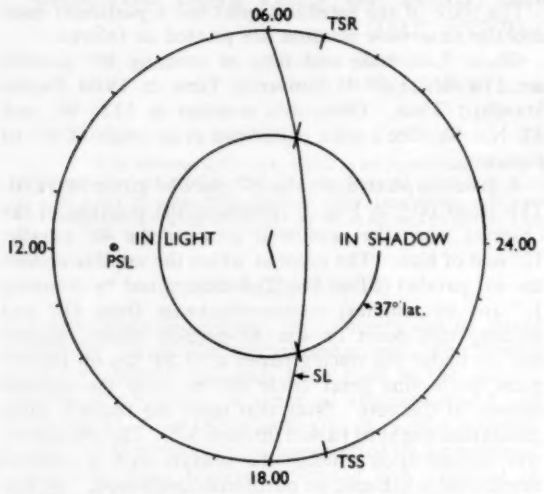

FIG. 4. Method of plotting shadow line by passing great circle through points on 37° latitude circle which represent time of sunrise (*TSR*) and time of sunset (*TSS*).

circle on to the tracing paper overlay; it is the shadow line (*SL*) at the Earth's surface. Plot the pole of this great circle (*PSL* of Fig. 4). In Fig. 4 it is a point 90° away along the great circle through 12.00, 24.00 and the North Pole (*N*) on the sunlit side of the globe. A line through *PSL* and the centre of the Earth represents the orientation of the Sun's rays striking the Earth. Next, plot the trace of the shadow line at some desired altitude, for example 200 miles, as follows. As shown on Fig. 3, a tangent to the Earth intersects an altitude of 200 miles about 18° away from the point of tangency. Thus the trace of the shadow line 200 miles high is a line everywhere about 18° away from the shadow line at the surface of the Earth. To plot this trace, let the pole

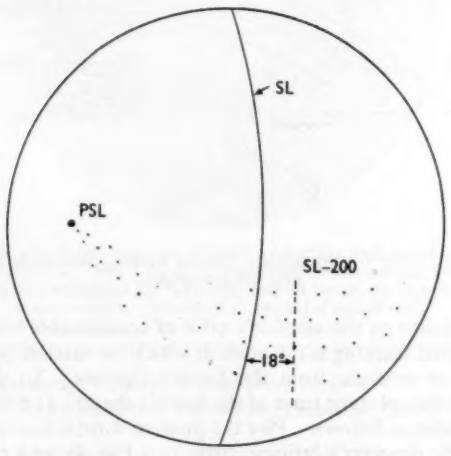

FIG. 5. Method of plotting shadow line at a height of 200 miles (SL-200)—a line 18° away from shadow line at surface (*SL*). *PSL* is pole of shadow lines.

(*PSL*) lie on different great circles that intersect the shadow line and along each one plot a point 18° away from the shadow line on the shadow side (Fig. 5). A line through the series of 18°-points lying within the shadow zone represents the trace at the Earth's surface of the shadow line 200 miles high. If the satellite's orbit is at a height of 200 miles and its trace is plotted with the 200-mile-high shadow line, the point at which the path of the satellite passes from sunlight to shadow or *vice versa* is apparent (see Fig. 7).

It might be desired to determine the azimuth from the observer's position to some point on the orbit. To do this recognize that the observer's position must be considered a pole and that azimuth must be measured along a great circle representing a plane normal to a line through the pole and the Earth's centre (see Fig. 6).

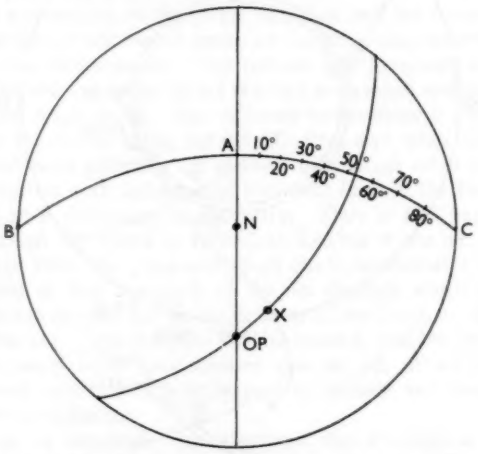

FIG. 6. Determining azimuth from observer's point (*OP*) to another point (*X*). Azimuth angle is read along great circle (*BAC*) the pole of which is observer's point. *N* is North Pole. In this example azimuth is 52°.

Mark a point (*A*) 90° from the observer's point (*OP* of Fig. 6) north along his meridian line, past the North Pole (*N*) and down the opposite side of the globe. Pass a great circle through this point, so oriented that its ends (*B* and *C*) define a line at right angles to the line through *OP*–*N*. Azimuths from *OP* are read along this great circle as the number of small circles crossed. For example, the azimuth for a line (thus also a great circle) from *OP* to *X* is read as 52° east of north, due north being represented by the line through *OP* and *N*.

Fig. 7 shows how a series of passes may be plotted with respect to sunrise and shadow line at 200 miles high. Also the observer's positions at the times of passes near sunrise are plotted.

As example, the plot shows that on the early pass of the seventh day at slightly before 04.00, the satellite would pass into sunlight far to the north-north-east of the observer's position. At the point of closest approach on this pass, the satellite would still be in shadow. In contrast, on the late pass on the seventh day at about

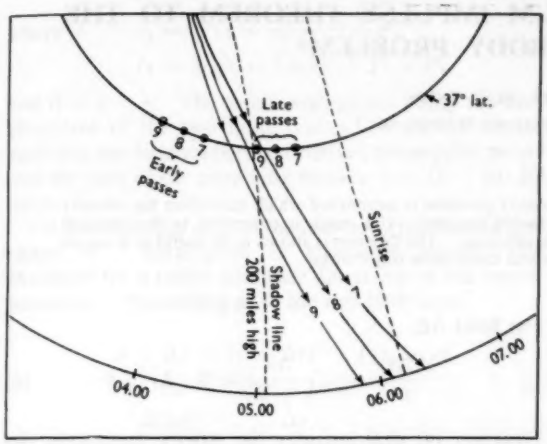

FIG. 7. Portion of net area showing plot of satellite orbit (long arrows) and times of passes over 37° latitude for a series of days, 7–9 of a given month. Circled points on 37°-latitude circle represent observer's position at pass times. Times are indicated along the circumference of net. Observer's positions for two consecutive passes on each of the three days are shown. Height of satellite assumed to be 200 miles so that point of passage into sunlight is represented by intersection of satellite orbit and trace of shadow line 200 miles high.

05.30, the satellite would pass much nearer, and at the point of closest approach the satellite would be south-west of the observer's point. The satellite would pass into sunlight at a point north-west of the observer's position. On the early pass of the ninth day, the satellite would not pass into sunlight until it had reached a point far to the south-east of the observer's point, too far to be above the observer's horizon. On the late pass of the ninth day, however, the satellite would pass into sunlight almost due south of the observer, and at this time close enough to be above the observer's horizon.

As before, the distance between observer and any point on the trace of the satellite's orbit, such as point of closest approach or point of passage from light to shadow, can be determined by rotating the net under the plot, until a great circle passes through the observer's point and the desired point and then reading the small circles lying between the two points.

For prediction purposes, the trace of the orbits can be precessed or shifted clockwise on the plot. For 1957α and 1957β and for 1958δ (1)* the rate of precession amounted to about 3° per day of absolute precession of the orbit in space plus 1° of apparent precession resulting from revolution of the Earth in its orbit.

Prediction of the times of passage far in advance with great accuracy can be rather complex. An approximation, however, can be obtained easily by plotting the time required for orbiting on semi-log graph paper. Fig. 8 shows the graph of 1958δ (1) during the part of

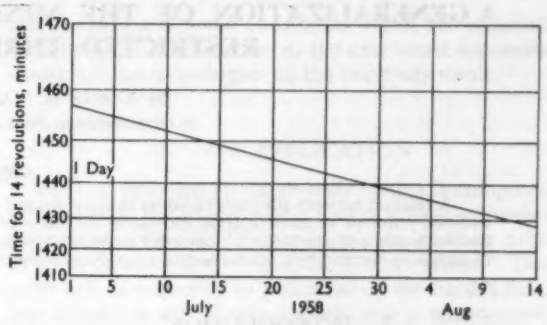

FIG. 8. Graph of minutes required for each 14 revolutions of 1958δ (1) from 1 July to 14 August, 1958, plotted on semi-log grid. Note nearly straight-line relationship.

its life when it had about 14 revolutions per day. The times for 14 revolutions are plotted and, it will be noted, approximate a straight line. When times of passes can be determined on successive days the time lag or gain per day can be plotted above or below 1440 minutes (the minutes in a day) respectively and a straight line extrapolation to future days should give a basis for approximate prediction of future passes. A curve giving much greater precision is given by Wakabayashi and Kirmser.[3]

The preceding examples are only a few in which the stereographic net and supplementary graphic methods can be used for rapid solution of Earth-satellite orbit problems. Such graphic methods are only as accurate as the scale of the plot. The stereographic net 8 in. in diameter can give only approximate values, yet this degree of accuracy has been found to be satisfactory for many visual and photographic tracking problems. The simplicity and rapidity with which the problems can be solved without resorting to elaborate mathematics is an important feature of the method. The net also provides a method for graphically plotting a number of major variables so that an overall visualization of the relations of orbit position, shadow line and pass times can be obtained.

ACKNOWLEDGEMNTS

Mary Lou Conant and Gertrude K. Wallace kindly assisted in the preparation and review of this paper.

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* *I.e.*, *Sputnik* 1, *Sputnik* 2 and the rocket case of *Sputnik* 3.

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A GENERALIZATION OF THE MINIMUM IMPULSE THEOREM TO THE RESTRICTED THREE-BODY PROBLEM*

By LOUIS G. VARGO,† M.S., Fellow
(Communication from Aeronutronic Systems, Inc.)

ABSTRACT

A relation between the path variables in the restricted three-body problem is established which minimizes the velocity addition required to cause a given change in the value of the Jacobi integral. This result is compared to the classical two-body case and applied to a lunar orbit problem of practical significance. The theorem is shown to be useful as a means of analysing the complex interaction of propulsion requirements and three-body trajectories.

I. INTRODUCTION

PERHAPS the most widely used result in spaceflight mechanics is what might be termed the minimum impulse theorem. It states that, given a conic orbit in a simple gravitational field, the velocity impulse required to change the orbital energy is minimized if applied at the point of closest approach to the force centre. The statement holds for both periodic and non-periodic orbits, and for all types of energy changes. Escape, capture, and re-entry manoeuvres are examples. We find no rigorous proof of this theorem in the literature,‡ so one will be given for reference to its extension to the three-body problem.

II. THE THEOREM FOR THE TWO-BODY PROBLEM

The total energy of a two-body orbit is constant.

$$E = \frac{v^2}{2} - \frac{k}{r} = \text{constant} \quad .. \quad .. \quad (1)$$

v and r are the instantaneous speed and radial distance respectively, and, k is the gravitational constant of the field. For each value of E, there exists a corresponding region of space which is attainable. Thus, for $E < 0$, the elliptic case, the attainable region is a sphere of radius, $a = -k/E$. All of space may be reached when $E \geqslant 0$, but the time required to reach a given point and velocity at that point depend on the exact value. For an orbital energy change ΔE, we can write

$$E + \Delta E = \frac{(v + \Delta v)^2}{2} - \frac{k}{r} \quad .. \quad (2)$$

so that

$$\Delta E = v\,\Delta v + \frac{(\Delta v)^2}{2} \quad .. \quad .. \quad .. \quad (3)$$

For fixed ΔE,

$$\frac{d(\Delta v)}{dv} = -\frac{\Delta v}{v + \Delta v} < 0, \ \Delta v > 0 \ .. \quad (4)$$

Equation (4) demonstrates the strictly monotonic decreasing behaviour of Δv with v; hence max. v implies min. Δv. An inspection of Equation (1) reveals that max. v occurs at the point of the original orbit closest to the centre.

III. EXTENSION TO THE RESTRICTED THREE-BODY PROBLEM

The restricted three-body problem concerns the motion of a particle in a field due to the gravitational forces of two other finite bodies revolving in circular coplanar orbits about the barycentre of the system. There exists an integral of the equations of motion which is analogous to energy in the two-body problem. This integral was first noted by Jacobi,[1] and carries his name.

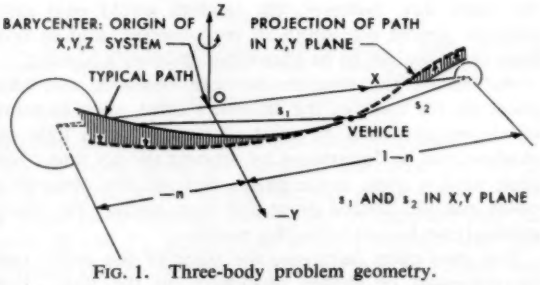

FIG. 1. Three-body problem geometry.

If x, y, z define a rotating co-ordinate system with origin at the barycentre as shown in Fig. 1,

$$J = v^2 - x^2 - y^2 - \frac{2(1-n)}{r_1} - \frac{2n}{r_2} = \text{constant} \quad (5)$$

* Manuscript received 8 December, 1958.
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‡ *Note added in proof.* The author has had called to his attention after submitting the present paper, a result obtained by S. Herrick,[4] which demonstrates the two-body theorem under the linear assumption of a "variation of constants" approach.

where $r_1 = \sqrt{(x+n)^2 + y^2 + z^2}$,

$r_2 = \sqrt{(x-1+n)^2 + y^2 + z^2}$,

and $0 < n < \frac{1}{2}$. The x-axis always lies along the line-of-centres of the two finite bodies. Units are chosen such that the distance between centres, the angular period and the sum of the attracting masses, $n + (1 - n)$, are unity.

J is the analogue of E of the two-body problem in that values of J correspond to attainable regions. See Moulton[2] for a rather complete discussion of the correspondence. Proceeding as in the two-body case,

$$J + \Delta J = (v + \Delta v)^2 - f(x, y, z),$$
$$\Delta J = 2v\Delta v + (\Delta v)^2 \quad .. \quad .. \quad (6)$$
$$\frac{d(\Delta v)}{dv} = -\frac{\Delta v}{v + \Delta v} < 0,$$

where $f(x,y,z)$ denotes the position-dependent terms in Equation (5). Again max. v implies min. Δv and from Equation (5), max. f implies min. Δv. To gain insight into where in space max. f might occur, it is convenient to transform $f(x,y,z)$ to a bi-polar form, *viz.*, $f(r_1, r_2)$, and confine our attention to the xy-plane. This is a case of much practical importance, since a desired manoeuvre is likely to be specified relative to either of the two attracting bodies and their plane of motion. Letting s_1 and s_2 be the projections of r_1 and r_2 on the xy-plane, $f(x,y,0)$ becomes

$$f(s_1\, s_2) = (1 - n)\left(s_1^2 + \frac{2}{s_1}\right) + n\left(s_2^2 + \frac{2}{s_2}\right) - n(1 - n) \quad .. \quad (7)$$

The condition for an extremum or stationary point of f is $df = 0$.

$$df = 2(1 - n)\left(s_1 - \frac{1}{s_1^2}\right)ds_1 + 2n\left(s_2 - \frac{1}{s_2^2}\right)ds_2 = 0 \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

Unfortunately all the stationary points of f give rise to min. f and hence min. v and max. Δv. This can be shown by considering the first and second partial derivatives of f with respect to s_1 and s_2. For s_1,

$$\frac{\partial f}{\partial s_1} = 2(1 - n)\left(s_1 - \frac{1}{s^2}\right) = 0 \quad .. \quad (9)$$

gives $s_1 = 1$. But

$$\left(\frac{\partial^2 f}{\partial s_1^2}\right)_{s_1 = 1} = 2(1 - n)\left(1 + \frac{2}{s_1^3}\right)_{s_1 = 1} = 6(1 - n) > 0 \quad .. \quad (10)$$

and similarly for s_2. Since the second partials never change sign, max. f will always occur at the boundary of some region in space restricted by the nominal path and perhaps additional constraints which are imposed. This situation is referred to as the unattained maximum condition and is analogous to the two-body result.

IV. AN APPLICATION

Suppose now that the three-body system is composed of the Earth, the Moon, and a rocket vehicle. Further suppose that we wish to establish a circular lunar orbit at some distance $\bar{s}_2 < 1$ from the Moon's centre. This orbit will subsequently be perturbed by the Earth's field, but initially it will closely approximate a selenocentric circular orbit. The manoeuvre must take place on the circle $s_2 = \bar{s}_2$. The turning losses associated with the capture will be zero for $ds_2 = 0$, that is, when transfer paths are tangential to $s_2 = \bar{s}_2$. A recent paper[3] by the author gives a discussion of the various types of losses including those caused by turning.

For $s_2 = \bar{s}_2$, s_1 lies between the values $1 - \bar{s}_2$ and $1 + \bar{s}_2$. As has been shown, max. f will occur at one of these two points. If $g_1(s_1)$ denotes the s_1-dependent terms of f,

$$g_1(1 - \bar{s}_2) - g_1(1 + \bar{s}_2) = \frac{4(1 - n)\bar{s}_2^3}{1 - \bar{s}_2^2} > 0 \quad (11)$$

so that $s_1 = 1 - \bar{s}_2$ gives min. Δv. Fig. 2 indicates the

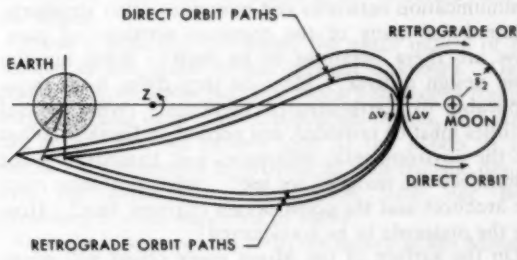

FIG. 2. Paths for min. Δv: lunar orbit establishment.

classes of paths that should be considered for both direct and retrograde lunar orbits when the launch direction is generally eastward. The mirror images of these paths about the x-axis should also be considered. For example, one might be willing to pay the propulsion penalties associated with a westward launch in order that the departure guidance requirements for a direct orbit be reduced. On the other hand, when $\bar{s}_2 \ll 1$, a direct orbit may be established at the off-optimum position, $s_1 = 1 + \bar{s}_2$. This could be done with an eastward launch without incurring large penalties since the expression in Equation (11) varies as $\bar{s}_2$.

It should be noted that the foregoing analysis in no way rules out the possibility that a transfer path could be selected which gives min. $\Delta v = 0$. The method does, however, allow the selection of a path to be based on, say, initial propulsion and/or guidance requirements and

performance. Since this selection may be made from only those paths which minimize $\triangle v$, we have a tool to solve what is essentially a double end-point problem. It is well known that the establishment of lunar orbits without additional thrusting in the vicinity of the Moon imposes severe accuracy requirements on the path variables at terrestrial departure. Use of the theorem allows these requirements to be relaxed and at the same time insures that the additional thrust increment will be minimized.

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BASIC DESIGN CRITERIA FOR MOON BUILDING*

By Professor JOHN S. RINEHART,† Ph.D.

ABSTRACT

After indicating the environmental conditions which will be encountered on the Moon, discusses their effect on the design of buildings for lunar use. A scale model of a proposed building has been constructed.

I. INTRODUCTION

MAN will, within the foreseeable future, construct permanent buildings on the Moon to serve as living quarters for Moon explorers, laboratories for astrophysical and astrochemical research, maintenance shops for the vehicles of the space traveller, stations for communication networks and numerous other structures required for many of the common activities of man. How are these buildings to be built? What are the basic design criteria? How do they differ from those applicable to Earth-situated buildings? What special facilities must be provided, not needed on Earth? What are the environmental differences and hazards? What determines the material we use? What problems must the architect and the construction engineer face? How are the materials to be transported?

On the surface of the Moon every object will weigh only one-sixth as much as on the surface of the Earth. The mass or inertia of each object is, however, independent of its location. *In design one must continually keep the distinction between mass and weight clearly in mind.*

II. ENVIRONMENTAL CONDITIONS

The environment of a building on the Moon differs markedly from its environment on the Earth. The Moon has no observable atmosphere. There is no haze, no clouds, no winds, no rain or snowstorms. The building is either bathed in intense sunshine or looks upon stark, black, cold space. It will be continuously plagued by the great gnat-like rain of interplanetary dust.

The Moon has lost its atmosphere, if it ever had any, because of its small size and, hence, low gravitational pull. Thus the atmospheric pressure is zero and any building constructed there must be internally pressurized with an atmosphere in which humans can survive.

The Moon's surface, unshielded by an absorbing atmosphere, can feel the full force of the Sun's rays and become extremely hot on one side while the other side will quickly have radiated its heat into space and become exceedingly cold. Day and night are each about two weeks long.

The temperatures on the surface of the Moon have been carefully measured, using a telescope equipped with a vacuum thermocouple. It was found that the surface of the Moon cools very quickly during an eclipse, reaching minimum temperature in 20 or 30 min. after the Sun stops shining. The temperature at lunar midday is 214° F. (101° C.), at sunset 32° F. (0° C.), and at midnight −243° F. (−153° C.). Curves showing the eclipse measurements and the temperature distribution at full moon are given in Fig. 1 and 2. From these diagrams it is possible to estimate the sort of temperature environment, maximum and minimum temperatures and rates of changes in temperature, any structure placed on the Moon will be subjected to. Any structure placed there must be able to withstand these extreme temperatures and especially the tremendous temperature gradients which will abound.

* Manuscript received 16 December, 1958.

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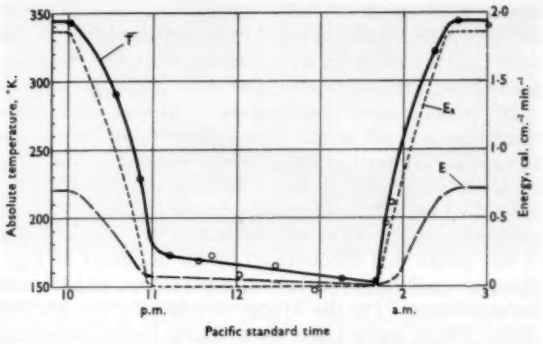

FIG. 1. Variation of the absolute temperature (T), the energy received from the Sun by the Moon (E_R), and the energy radiated (E), during the total lunar eclipse of 14 June, 1927.

The ultra-violet radiation, normally absorbed by the Earth's atmosphere, will be sufficiently intense to render panes of glass or plastic useless as windows through discoloration. Hence, shutters must be provided for such windows.

The Moon is continually bombarded by particulate matter: cosmic rays, charged particles; and meteoric particles. Not much is known about the rate of influx of cosmic rays, although recent records from the satellite, *Explorer III*, indicate that they are considerably more abundant that we have thought. They probably do not present a health hazard but they may be sufficiently abundant to discolour glass or plastic after long exposure.

It is also not possible to define very accurately the nature and distribution of meteoric matter so as to estimate it as a potential hazard to structure. According to Whipple, extraterrestrial material exists in three forms: (i) *interplanetary dust* (the most abundant, ranging in size from 1 to 300 microns in diameter; (ii) *meteors*—fragile, porous bodies of low gross density; and (iii) *meteorites*—solid chunks of iron and stone. The velocity with which any of this material might strike the Moon ranges from 1·5 to about 44 miles/sec. There will be no atmosphere to check its velocity, as is the case with the Earth, where the interplanetary dust and the meteors are rendered impotent.

The fall of a meteorite is a relatively rare event: about five per day reach the Earth. Interplanetary dust is by far more abundant in space, with the abundance of this dust in the vicinity of the Moon being about 5×10^{-21} g./cm.^{3}. The Moon sweeps up this material at the rate of 110 tons per day.

Thus the chance of a large building being struck by a meteorite or a meteor is negligible, one hit in perhaps several thousand years. Interplanetary dust is the real hazard and we do not know how great it is. The particles are small, and even though of great velocity, could be easily warded off with an umbrella-like shield. Our best estimate is that about three or four particles with diameters ranging from 0·0002 to 0·0004 in. would strike each square yard of exposed surface per day.

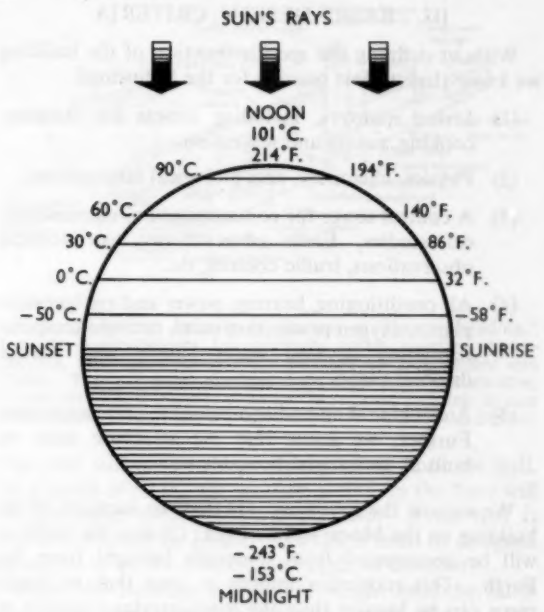

FIG. 2. Temperatures on the Moon.

A meteoric shield must be a part of any structure built on the Moon.

From a practical viewpoint, the exact nature of the surface of the Moon is our greatest unknown. On a grand scale we know that the Moon's surface is fraught with large and deep craters, mountain ranges, and great flat areas. But we cannot look at the Moon in the intimate detail needed to provide us with realistic design data for construction. Resolution with our best telescopes is some hundreds of yards.

Opinion is now divided as to the nature of the Moon's landscape. At a U.S. Air Force symposium on this subject in April, 1958, three eminent astronomers summarized their variant ideas:

(1) "the maria (large dark flat areas) are almost certainly covered with lava and will make firm landing spots for Earth's spaceships."

(2) "The rock has turned slowly to dust by bombardment of rays and particles from the Sun and space. The dust, kept stirred up by the same agents that formed it, has flowed like a slow liquid into the Moon's low places so the maria are not filled with lava, but with dust perhaps several miles deep. Dust near the surface may be as fluffy as baby powder. Unwary ships might disappear in dry quicksand."

(3) "Although the Moon may have plenty of dust, its surface has been solidified. There may be a thin layer like dust on a grand piano but underlying material, cemented together (not stirred up) by bombardment from space, is probably 'crunchy' and strong enough to support our alighting spaceships."

With this lack of knowledge and great divergence of opinion we can only design for the worst condition: a sea of dust upon which we must float our structures.

III. BASIC DESIGN CRITERIA

Without defining the specific function of the building we know that it must provide for the following:

(1) Living quarters, including rooms for sleeping, cooking, eating and recreation.

(2) Physics, chemistry, and biological laboratories.

(3) A control tower for communication, meteorological studies, Earth observations, astronomical observations, traffic control, etc.

(4) Air conditioning, heating, power and refrigeration plants, oxygen production units, extreme-temperature-regulating devices, water supply and sewage disposal plants.

(5) A machine shop and equipment maintenance area. Further, we know that the structure must be built as an integral floatable unit.

We assume the following: (1) that the location of the building on the Moon will be fixed; (2) that the building will be constructed from materials brought from the Earth. This restriction implies at once that no single piece can be heavier than the load-carrying capacity of the cargo space of our future Moon rockets; (3) that the building will provide the functions listed above; and (4) that it will be a permanent-type building in the sense that it will be occupied on a continuing basis over several years' time.

A Moon building presents its own peculiar problems and first is the matter of gravity. The force of gravity on the Moon is approximately one-sixth that on the Earth. This means that the deflection of a cantilever beam or any other load-supporting beam or column will be only one-sixth as great as it would be on Earth. Changes in gravity will not affect the strength properties of the materials. For design purposes we can, in all static situations, (*n.b.*, only static, not dynamic) replace the "g" of 32 ft./sec.^{2} which repeatedly appears in our strength of materials formulae by one-sixth its value, say 5 ft./sec.^{2} A whole new field of design is opened up. It is as if we had an exceedingly high-strength, lightweight construction material.

We must, however, be wary of any dynamic situation. We do not change the mass of our material by transporting it to the Moon. It would be just as difficult to accelerate a car on the Moon as it is on the Earth. Thus, designs involving vibratory or rotary motion must conform to the normal terrestrial pattern. An electric generator designed for lunar use would not appear substantially different from a terrestrial one.

Reduction in gravity will influence the convective flow of air and the rate of flow of liquids downhill. These changes are likely to become important in design of the heating, power, water, sewage, and ventilating systems.

Ramps and stairs can be much steeper because man will be able to lift himself with one-sixth the effort required on Earth. A crane designed for a 1-ton load on the Earth can lift at least 6 tons on the Moon. We must, on the other hand, be careful with our elevators for here we are *accelerating* and *decelerating* masses.

No consideration need be given to wind or snow loads since they will not exist. Our major stresses now come from the artificial atmosphere contained within the hermetically sealed building. Normal atmospheric pressure, 14·7 lb./in.^{2}, is a realistic figure to use for design purposes; 10 lb./in.^{2} would be sufficient. The problem is not unlike that encountered by the designers of high-flying aircraft except perhaps in one respect, which could be significant. On the Moon we can play the gravitational forces against the air pressure forces, achieving some kind of equilibrium which may gain us an advantage. This is a matter that needs looking into. Broad expanses of curved structures can be used but we must tie the whole together with rods or similar means so that it does not suffer an internal explosion.

Rapid, intense heating and sudden, severe cooling present difficult, but certainly solvable, design problems. The parts of the structure becoming shaded will immediately become exceedingly cold, while those in the sunlight will remain heated to a high temperature. During the lunar day, when the Sun shines upon the structure, devices must be provided to regulate the influx and efflux of heat. These should be tied together to the heating and ventilating systems. But we must also be prepared to be without our principal energy source, the Sun, for two weeks at a time. This means providing energy storage facilities of no mean proportion.

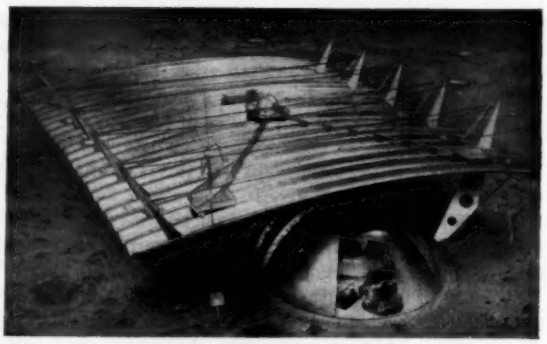

FIG. 3. Scale model of "Moon building" designed as a permanent structure to house living quarters, laboratories, maintenance shops, etc. In the foreground is a plastic bubble observatory protected by sliding metal doors from the intense ultra-violet radiation. The upper section over the structure is a protective meteoritic shield. The dome in the centre is the traffic control tower. The building would be 340 ft. iong, 160 ft. wide and 65 ft. high; the shield would measure 480 × 380 ft. and be 83 ft. above the ground.

The potential hazard from cosmic rays, while still one of the big unknowns, is probably not great enough to warrant modifying constructional practices. Eventually the living quarters may be lined with thin sheets of lead.

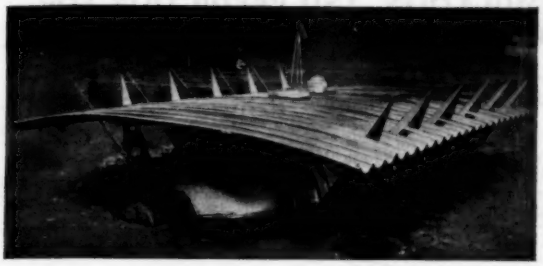

FIG. 4. Rear view of scale model of "Moon building," showing detail of entrance and of air-lock chamber. The building and shield would be fabricated of pre-engineered aluminium alloy sheets secured by nut and bolt fasteners and welded structure connexions.

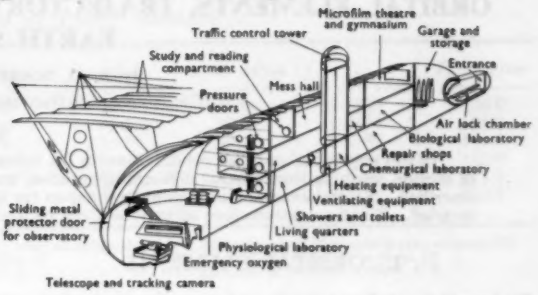

FIG. 5. Cut-away drawing of interior of "Moon building," showing compartments for research, living quarters, observatories, etc. Entrance is made through air lock at one end (*right*). Pressure doors separate main areas from one another, to prevent loss of internal pressure throughout building in case of accidental penetration of overhead protective shield by meteor.

The bombardment by meteoric matter is serious but can be dealt with. The best approach is to use the scheme long in use by tent dwellers to protect themselves from the fury of rainstorms; a canvas canopy covering, placed above and separated some distance from the roof of the tent, which dulls the force of the impact of the raindrops and diverts the material away from the roof of the tent. On the Moon, the canopy must be of metal, not canvas, whose thickness will be sufficient to stop meteoritic dust. An aluminium shield $\frac{1}{32}$in. thick should be sufficient. We cannot hope to protect against chance encounters with large meteoric bodies anymore than a canvas shield protects against large hailstones. Provision should be made for replacing sections of the shield as they become damaged.

Finally, we are concerned with foundations for the building and here is the greatest difficulty. There seems to be but little else to do but to design the building as a structure which floats in a stationary ocean of dust, anchored in place by large, heavy blocks suspended by long cables from the body of the structure. In many ways its construction will resemble that of a ship at anchor, a freely-floating, self-contained unit. The building need not be streamlined. Fortunately, also, it need not be built to withstand the tumultuous forces exerted by a watery ocean. The dust on the Moon is as calm as a mill pond.

According to Archimedes' principle a body immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces. A 10,000-ton ship for example, has 320,000 ft.^{3} (1 ft.^{3} of water has a mass of 62·4 lb.) immersed when it is floating. Now, how will our dust ocean act in this respect? We are safe in concluding that it will act as a fluid of low density: for design purposes, about 0·5 times the density of water or 30 lb./ft.^{3}. Thus the lower part of our building will be covered with dust, the volume, V, so covered being given by

$$V\,(\text{ft.}^3) = \frac{\textit{Total mass of building}\ (\text{lb.})}{30}$$

The dust will tend to support the lower floor, or hull. At a depth of 60 ft., the pressure acting on the floor will be just equal to atmospheric pressure. If the hull is embedded to depths greater than this it must be designed so as not to be crushed by the weight of the dust.

Since the building is floating, weight must be fairly uniformly distributed if it is not to topple over or settle in unevenly.

If the Moon's surface proves to be sufficiently solid it will provide normal support for the building and may be used as foundation blocks.

IV. THE DESIGN.

There is no one building uniquely qualified for placement on the Moon. Design requirements allow as well as demand a diversity of structural types, proportions, materials and forms. The portable and inflatable plastic balloon house is a perfectly practical type of temporary housing.

Permanent housing must be fabricated from more durable materials. Aluminium suggests itself immediately because of its high strength, low weight, and ease of fabrication. Aluminium also provides a good reflecting surface which aids in cooling problems.

The basic scientific information needed to complete first designs of functional and attractive buildings for for use on the Moon are at hand. Our task has been the very specific one of taking these scientific guide lines and producing a practical model.

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ORBITAL ELEMENTS, TRAJECTORY SIMULATION, AND PREDICTION FOR EARTH SATELLITES*

By A. D. WASEL,† A.B., M.Ed., Ph.D.
(Communication from the Lockheed Aircraft Corporation)

ABSTRACT

In this paper, the so-called orbital elements are introduced and their notations indicated. The forms of the equations of motion resulting from several different approaches are shown. A trajectory simulation utilizing statistical methods is described. Several examples of possible techniques for determining values of orbital elements for prediction purposes are detailed. Finally, combinations of various kinds of tracking data are listed.

I. ORBITAL ELEMENTS

To locate a satellite vehicle and describe its motion, one needs certain parameters or orbital elements. Under the assumption of an Earth central force field, the plane determined by the position and velocity vectors intersects the equatorial plane of a reference sphere in a line called the *line of nodes*. The position of the intersection of the line of nodes with the ascending trace of the plane of motion on the sphere, relative to the direction of Greenwich, is called the longitude of the ascending node, and is denoted by ϕ_N. The angle at the ascending node between the equatorial plane and the plane of motion is called the inclination, γ. The angle from the direction of pericentre (see Fig. 1) to the ascending node

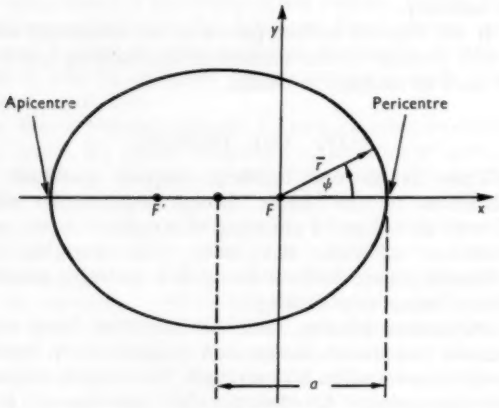

FIG. 1.

in the direction of motion is called the argument of pericentre and is denoted by c. The semi major axis of the elliptical path is denoted by a and its eccentricity by ϵ. The angular distance from the pericentre to the vehicle, the true anomaly, is denoted by ψ. Thus ϕ_N and γ locate the plane of motion, c orients the ellipse of motion in the plane, a indicates the size, ϵ indicates the shape, and ψ locates the vehicle on the ellipse. These basic elements are shown in Fig. 2. See Table I for

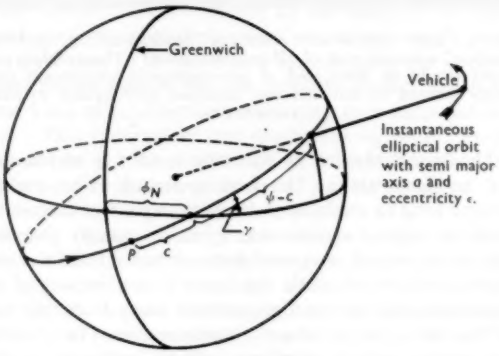

FIG. 2. Orbital elements

a listing of orbital elements of the first six I.G.Y. satellites. The anomalistic periods T, rather than true anomalies, are given as a matter of interest.

II. EQUATIONS OF MOTION

The standard Keplerian two-dimensional position and time equations (see Ref. 1), together with equations for latitude θ and longitude ϕ obtained by spherical trigonometry, form a set of equations of motion for Keplerian motion. They are:

$$\left.\begin{aligned} r &= a(1-\epsilon^2)/(1+\epsilon\cos\psi) \\ \sin\theta &= \sin\gamma.\sin(\psi-c) \\ \tan(\phi-\phi_N) &= \cos\gamma.\tan(\psi-c) \\ \omega\tau &= [E-\epsilon\sin E]_{E_0}^{E} \end{aligned}\right\} \quad . . \qquad (1)$$

The principal effects of oblateness of the Earth are precession of the nodes and rotation of the line of apsides. The secular (long-time) behaviour of ϕ_N and c might be approximated by linear functions, say $\phi_N = \phi_{N0} + (\alpha - \Omega)\tau$ and $c = c_0 + \beta\tau$. α is the precession rate, β the apsidal rate, and Ω the Earth rotation rate. Further, the effect of air drag can be incorporated into Equation (1) by adding certain functions of the elements to the right members of the first three equations.

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TABLE I—*Orbital Elements of I.G.Y. Satellites*

NAME	CODE	LAUNCHING	ϕ_N, deg. E	γ, deg.	c, deg.	a, N. miles	ϵ	T, minutes
Sputnik I (rocket)	1957α (1)	4 Oct. 1957	334·3*	65·3	46·0†	3778	0·0487	96·0
Sputnik II ..	1957β	3 Nov. 1957	259·65**	65·4	34·0††	3946	0·0971	104·0
Explorer I ..	1958α	31 Jan. 1958	342·95	34·5	120·76	4067	0·1387	114·6
Vanguard ..	1958β	17 Mar. 1958	129·2	34·5	310·0	4698	0·1951	135·0
Explorer III ..	1958γ	26 Mar. 1958	243·87	33·5	91·02	4246	0·1661	115·9
Sputnik III ..	1958δ	15 May 1958	027·9***	65·2	317·12†††	4400	0·0818	100·8

* Right ascension of ascending node at epoch I.
† Argument of pericentre at epoch I. Epoch I is 1957 Oct. 7.0, U.T.
** Right ascension of ascending node at epoch II.
†† Argument of pericentre at epoch II. Epoch II is 1958 Jan. 22.0, U.T.
*** Right ascension of ascending note at epoch III.
††† Argument of pericentre at epoch III. Epoch III is 1958 Feb. 6.89874, U.T.

The mathematical technique called the variation of parameters applied to (1) yields an alternate set of equations of the form:

$$\left.\begin{aligned} \dot{\phi}_N &= f_1(\phi_N, \gamma, c, a, \epsilon, \psi) \\ \dot{\gamma} &= f_2(\phi_N, \gamma, c, a, \epsilon, \psi) \\ &\cdot \\ &\cdot \\ &\cdot \\ \dot{\psi} &= f_6(\phi_N, \gamma, c, a, \epsilon, \psi) \end{aligned}\right\} \quad .. \qquad (2)$$

See Ref. 2 for a discussion of equations of this form.

A non-Keplerian method, using a potential function for the Earth's potential field, yields still other alternate forms of the type:

$$\left.\begin{aligned} \ddot{x} &= F_1(x, y, z, \dot{x}, \dot{y}, \dot{z}) \\ \ddot{y} &= F_2(x, y, z, \dot{x}, \dot{y}, \dot{z}) \\ \ddot{z} &= F_3(x, y, z, \dot{x}, \dot{y}, \dot{z}) \end{aligned}\right\} \quad .. \qquad (3)$$

where x, y, z are coordinates in an appropriate frame of reference. The last equation of (1), being transcendental, requires iterative techniques for solution, calling for large-scale digital computers. Equation systems of the form (2) and (3) require step-by-step integration techniques and, also, can only be done on large-scale machines.

III. SIMULATION

From a table, or equivalent, one can employ normal deviates, having a mean value of zero and a standard deviation of unity, to generate a simulated trajectory. This can be done by choosing a set of initial conditions ($\mathbf{r}$, $\mathbf{v}$) or equivalently (ϕ_N, γ, c, a, ϵ, ψ) and letting time advance in a chosen set of equations of motion. Then appropriate coordinate transformations will yield a reference trajectory relative to a certain fixed tracking station. Denote points of this reference trajectory by points x', y', and z'. The Earth's oblateness should be taken into account here. Now transform x', y', z' into local polar coordinates. Denote points of this (horizon) trajectory by A', α', S' representing azimuth, elevation angle, and slant range respectively. Then a simulated observed trajectory is given by:

$$\left.\begin{aligned} A &= A' + \sigma_A \chi \\ \alpha &= \alpha' + \sigma_\alpha \chi \\ S &= S' + \sigma_S \chi \end{aligned}\right\} \quad .. \qquad (4)$$

where σ_A, σ_α, and σ_S are standard deviations representing the error in measuring the quantities A, α, and S respectively. These standard deviations could be composite, comprising errors of different kinds, such as are inherent in the tracking gear, propagation, and others. An important use of the simulated trajectories is the study of effects of errors on the trajectory. This can be done by comparing the reference and simulated trajectories for chosen standard deviations.

IV. PREDICTION

To predict requires the knowledge of position and velocity or, equivalently, the initial values of the orbital elements. Complete methods of getting these initial conditions from various types of observations will be a subject of a later paper. For the present, a few techniques will be shown for computing first approximations.

For example, see the following method for determining γ and ϕ_N if geocentric latitude and longitude are given for two times. The assumption is made here that the time difference is sufficiently small that the precession of the nodes is negligible. An examination of Fig. 3

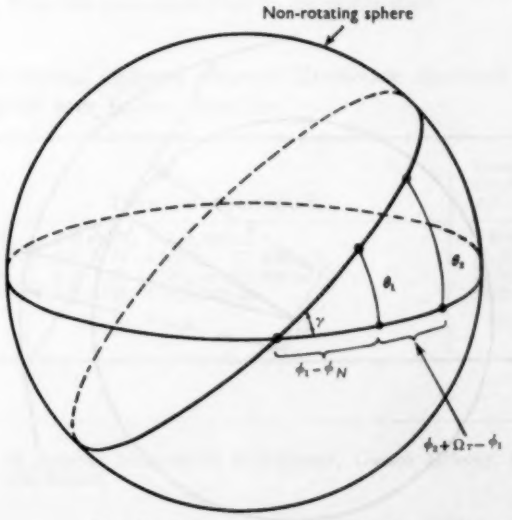

FIG. 3. Determination of inclination

and application of spherical trigonometry will show the derivation of the two following equations

$$\left.\begin{aligned}\sin(\phi_1 - \phi_N) &= \tan\theta_1.\mathrm{ctn}\,\gamma \\ \sin[(\phi_1 - \phi_N) + \phi_2 - \phi_1 + \Omega\tau] &= \tan\theta_2.\mathrm{ctn}\,\gamma\end{aligned}\right\} \quad (5)$$

where Ω is the Earth rotation rate and τ is the time difference. These two equations solved simultaneously yield ϕ_N and γ.

Consider another technique. This time we are assuming a spherical Earth and a nearly circular orbit (see Fig. 4). A determination of A_1 and A_2, together

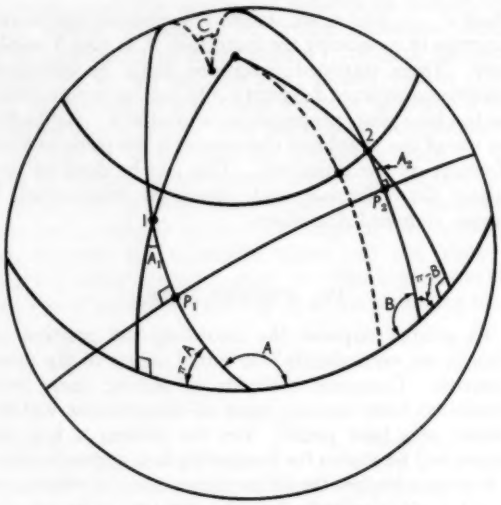

FIG. 4. Determination of semi major axis

with corresponding times, is made from the tracking (angular) data of the passes at station one and station two. The angles A and B are determined by computing their supplements (as shown in the figure) using spherical trigonometry. Then the angle C is computed, again by spherical trigonometry. The mean angular rate ω is computed by dividing C (in radians) by τ, the interval of time between intercepts P_1 and P_2. It is assumed that τ is sufficiently small that nodal precession is negligible. The semi major axis a of the orbit is then obtained from Kepler's third law.

Here, the other orbital elements might be computed by first calculating slant ranges to accompany the angular data in the element determination. This can be done by use of the triangle OTV in Fig. 5.

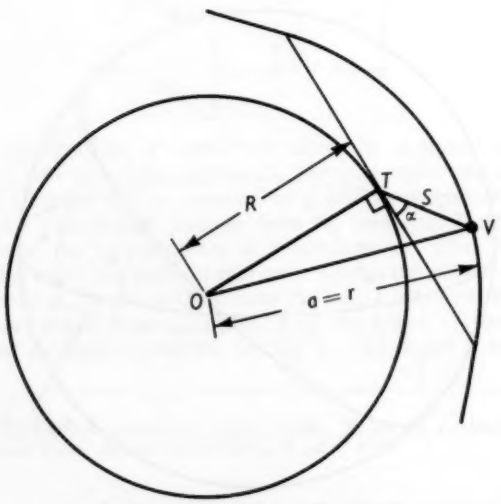

FIG. 5. Determination of range

V. TYPES OF DATA

Many combinations of various types of tracking data are being tried in connection with the IGY. Some of these are listed in Table II.

TABLE II.—*Tracking Data Types*

DATA IDENTIFICATION	NOTATION	QUANTITY
Radar	A α S	azimuth elevation range
Minitrack	$\cos a$ $\cos b$ $\cos c$	x-direction cosine y-direction cosine z-direction cosine
Direction Finder ..	A α	azimuth elevation
Doppler	ν	received frequency
Optical	r.a. δ	right ascension declination

VI. SUMMARY

Newtonian mechanics employing Keplerian principles permit us to develop theories, which with the aid of modern computing machinery, can be expected to yield orbital elements (as, for example, by techniques similar to those outlined in Section III) for prediction by (1) or (2) of Section II, or to provide instantaneous position and motion for use as initial conditions in prediction by (3) of Section III. Refinements of these methods will no doubt lead us to greater knowledge of geophysical constants describing the shape and composition of the Earth. Also, the extensions of these theories, necessary for lunar and interplanetary simulated trajectories, will not present great difficulties.

LIST OF SYMBOLS

$\bar{r}$	=	position vector
v	=	velocity vector
x, y, z	=	rectangular coordinates
r, θ, ϕ	=	co-spherical coordinates
ϕ_N	=	nodal longitude
γ	=	inclination
c	=	argument of pericentre

a = semi major axis of (instantaneous) ellipse
e = eccentricity of (instantaneous) ellipse
ψ = true anomaly
E = eccentric anomaly.
T = period
P = projection of pericentre on reference sphere
Ω = Earth rotation rate
ω = mean angular rate
R = (average) earth radius
χ = a normal deviate
A = azimuth angle of satellite
α = elevation angle of satellite
S = slant range of satellite
τ = time elapsed from initial time to present

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SOME REMARKS ON FREE RADICALS AND THEIR POSSIBLE USE IN ROCKET PROPULSION*

By OLGIERD WOŁCZEK,† Fellow

ABSTRACT

The possibilities of using nuclear and corpuscular non-nuclear radiations for producing free radicals are examined. The use of beta and alpha rays from isotopes and of radiation produced inside nuclear fission reactors are considered. The proposed method would seem to be of some practical value.

I. INTRODUCTION

GENERALLY speaking, the term *free radicals* means atoms or groups of atoms in the metastable state. According to Zwicky[1] one can distinguish here electron-, spin-, and atom-metastable systems. In principle, and from the point of view of rocket propulsion, the last type are of greater interest. In this case it is a matter of atoms or atom systems whose reactions are accompanied by considerable release of energy. The amount of energy is often much greater than the corresponding amounts of energy released in the most advantageous chemical exothermic reactions (see Table I).

In this paper a matter possibly of great interest has been omitted, namely the metastable system HHe postulated by Zwicky[1], which is still unknown; attention has been paid to the well-known and comparatively easy to obtain radical—atomic hydrogen (H). As regards energy, it is most advantageous (see Table I) and is particularly notable for the high value of specific impulse (Table II).

There are many known methods for obtaining free radicals. In all cases it is obvious that great energies must be involved. The amount of energy there involved must equal the amount released later in the return from the metastable state to the stable state.

TABLE I.—*Comparison between the Energies Released in Typical Ordinary Chemical Exothermic Reactions and Those Released in Some Typical Free Radical Reactions.*

	Chemical reaction	Energy released, cal./g.		Reaction of free radicals[4]	Energy released, cal./g.
1	$2\,O_2 \rightarrow 3\,O_3 + 69{,}000$ cal.(2)	710	6	$2\,N \rightarrow N_2 + 224{,}900$ cal.	8030
2	$2\,Al + 1\frac{1}{2}\,O_2 \rightarrow Al_2O_3 + 380{,}000$ cal. ..	3730	7	$3\,H + N \rightarrow NH_3 + 277{,}000$ cal.	16,260
3	$H_2 + \frac{1}{2}\,O_2 \rightarrow H_2O + 68{,}520$ cal.	3810	8	$4\,H + C \rightarrow CH_4 + 363{,}500$ cal.	22,660
4	$3\,H_2 + O_3 \rightarrow 3\,H_2O_{liq} + 239{,}560$ cal.‡ ..	4440	9	$2\,H \rightarrow H_2 + 103{,}240$ cal.	51,210
5	$B_2H_6 + 2O_3 \rightarrow B_2O_3 + 3\,H_2O + 620{,}000$ cal.	5000			

‡ Evaluated on the basis of reaction 1.

* Manuscript received 8 August, 1958.
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TABLE II.—*Comparison of the Values of Specific Impulse I_{sp} of Various Rocket Propellents (According to Sutton[5]).*

	Source of energy	Specific impulse (I_{sp}), sec.
1	Ordinary chemical fuels	200–300
2	High-energy chemical fuels ($e.g.$, $F_2 + H_2$)	340–440
3	Free radicals	400–1800
4	Free radicals: H	2160†

† Maximum theoretical value.

It is not the aim of the author to make a systematic review of all the methods of free radical production; it is possible to make use of such different sources of energy as:

electric arc,
high frequency electrical discharge,
nuclear radiations,
corpuscular nonnuclear radiations,
solar radiation, etc.

Only the possibility of using nuclear radiations and corpuscular nonnuclear radiations (such as electron beams from accelerators) will be discussed. This method (at any rate, at first sight) seems to be particularly promising.

II. USE OF BETA-RADIOACTIVE ISOTOPES

Considering methods of producing free radicals it is necessary to note diverse types of nuclear or corpuscular radiation:

(*a*) beta rays (or electron beams from accelerators),

(*b*) alpha rays (or beams of other heavy charged particles),

(*c*) radiations produced inside nuclear reactors—neutron beams and gamma rays.

Let us consider separate cases. As regards beta rays, here it would be advisable to make use of easily available substances—artificial radioactive isotopes produced in large quantities in nuclear reactors, such as ^{89}Sr, etc. (see Table III).

When used in practice these substances have to be suitably shaped so that the raw material from which the free radicals are to be produced flows in the immediate vicinity of the radioactive substance. It would be possible to have the substances in the following forms:

(*i*) porous matter,

(*ii*) 'wool' (fibres),

(*iii*) pipes,

made of either metallic or ceramic material.

In each case the radioactive substance would have a well-developed surface ensuring a particularly easy contact with the stream of raw material yielding the free radicals. However, both the porous matter and 'wool' (fibres) suggested above would strongly resist the flow of the raw material. In this case, the contact of the raw material with the radioactive source of energy would be comparatively prolonged—a favourable condition for a rise in the concentration of the free radicals produced. In addition, the irradiation would simultaneously cause a considerable rise in temperature of the raw material—an undesirable effect. Free radicals should have as low a temperature as possible before being used. Then the probability of their transformation into a stable state too early is small.

Moreover, the raw material itself (hydrogen or similar materials) would have to be in a state as dense as possible, *i.e.*, not gaseous, but liquid. It is then that the probability of radiation absorption is comparatively great. However, this necessitates low temperatures of the order of a few (in the case of hydrogen) or at any rate a few tens (oxygen, nitrogen) degrees Kelvin, so that flow resistance would cause the raw material to remain in the radiating substance for a prolonged time—an unacceptable condition.

TABLE III.—*Characteristic Data of Some Beta-Radio-active Isotopes.*

Isotope	Halflife, T	Maximum Energy of the Beta Radiation, MeV.	Mass of 1 Curie, g./Curie	Maximum Range in Liquid Hydrogen,* cm.	Density $^{20}\rho$, g./cm.^{3}	Number of Curies per unit mass, Curies/g.	Energy, cal./Curie/sec.	Surface of 1 Curie,† cm.^{2}	Energy, cal./g./sec.	Surface of 1 g.,† cm.^{2}
^{143}Pr	13·7 days	1·0	$1·5 \times 10^{-5}$	5·43	6·8	$6·7 \times 10^{4}$	$1·4 \times 10^{-2}$	$2·2 \times 10^{-3}$	94	147
^{89}Sr	53 days	1·5	$3·6 \times 10^{-5}$	9·26	2·6	$2·8 \times 10^{4}$	$2·1 \times 10^{-3}$	$1·4 \times 10^{-2}$	59	390
^{144}Ce	290 days	0·35	$3·2 \times 10^{-4}$	0·43	6·8	$3·1 \times 10^{3}$	$4·9 \times 10^{-4}$	$4·7 \times 10^{-2}$	1·52	146
^{90}Sr	28 years	0·61	$7·0 \times 10^{-3}$	2·43	2·6	$1·4 \times 10^{2}$	$8·4 \times 10^{-4}$	2·7	0·12	380
^{137}Cs‡	33 years	0·53 1·19 (5%)	$1·3 \times 10^{-2}$	1·81	1·9	$7·7 \times 10$	$8·0 \times 10^{-4}$	6·8	0·062	523

* Liquid hydrogen with density 0·071 g./cm.^{3} (20° K.). † Layer thickness = 10^{-3} cm. ‡ Melting point, $t_m = 28·5°$ C.

Thus, the radioactive substance should be in the form either of straight fibres, or better of pipes: the latter would give little resistance and the cooling would be easy and effective.

Radiation from isotopes could be effectively used only if these were in the form of films with a thickness of not more than several tens of microns. Should the the films be thicker, there would be strong internal absorption of the radiation. Moreover the working fluid should flow on both sides of the isotope film to make good use of the radiation, which is emitted in the whole solid angle.

However, it is not possible to use pipes with walls 10^{-3} cm. in thickness and so the isotopes would only form a coating on pipe of metal, ceramic or other suitable material; a considerable part of their radiation would then be lost, owing to absorption in the underlying base.

Approximate calculations for a few typical beta radioactive isotopes permit an estimation of the order of magnitude of the energy which would be available for the eventual process of producing free radicals (see Table III). The results are not encouraging. It is apparent that even in the case of comparatively short-lived radioactive isotopes such as ^{143}Pr or ^{89}Sr the energy radiated from a surface some hundreds of square centimetres in area is, at most, of the order of magnitude of tens of calories per second. Much of this energy is absorbed in the liquid hydrogen layer, which is a few centimetres thick, and a part of it is lost by absorbtion by the underlying base.

Let us consider more closely the instance of the eventual use of ^{89}Sr. From Table III, the layer of flowing liquid hydrogen must then have a thickness of about 9·26 cm. To simplify things let us neglect absorption by the underlying base. Then 1 g. ^{89}Sr would yield energy at the rate of 59 cal./sec. in the hydrogen layer (390 cm.^{2} in area), or 9·4 cal./g. hydrogen/sec. In view of the absorption of a part of the radiation in the base the actual amount of energy at our disposal would be even smaller.

This is a negligible quantity when compared with the energy necessary for transforming 1 g. of hydrogen completely into free radicals (51,210 cal.). Even if the time of irradiation was increased to a few minutes the amount of energy thus yielded would be smaller than the required 51,210 cal. by almost two orders of magnitude. Moreover, we should remember the necessity for high-velocity flow of the liquid hydrogen and the more-or-less limited length of the pipes carrying the radioactive isotopes.

Furthermore, only a very small part of the energy of the beta radiation is actually used for breaking bonds in the hydrogen molecules. In general, out of the total energy of the beta radiation, about 1 MeV. when passing through matter, approximately one-third is used for ionization and a little less than two-thirds for exciting the atoms of the absorbent. In this case the amount of energy which would actually be used for breaking molecular bonds and producing free radicals will certainly be less than 1%.

So the above proposition does not solve the problem. It is worth while, however, to consider whether in this instance we could use radioactive materials of very short half-life, releasing a considerable quantity of energy in a short time. Then construction of pipe systems or fibre beams with radioactive coatings are out of the question. Instead, a mixture of liquid raw material could be produced; for instance hydrogen with a dispersed radioactive substance. Should isotopes of the type of ^{24}Na be used, then the amount of energy available would be very great. For example, ^{24}Na ($T = 14{\cdot}8$ hr.) releases as much as 56,000 cal./g./sec.; most of this is provided by 1·39 MeV. beta radiation. Should the concentration of the isotope suspension in hydrogen amount only to 10%, then even in a period of a few seconds the released energy would result in the production of a great number of free radicals.

The considerable amount of energy released would naturally cause a rapid rise in the temperature of the mixture, which would be most undesirable from the point of view of the stability of free radicals. However, it seems that in this case such circumstances would not be an essential handicap—the mixture, eventually diluted with additional substance, would simply form the working fluid of the rocket engine.

The strong gamma radiation from ^{24}Na would not permit use of this substance near the Earth—especially in the vicinity of inhabited areas—but at a large distance from the surface it could be used without limitations, as it rapidly undergoes transformation into a stable magnesium isotope which is not at all noxious. Thus only magnesium dust and not the ^{24}Na emitted from the rocket exhaust would come down into lower layers of the atmosphere.

III. USE OF ALPHA-RADIOACTIVE ISOTOPES

What can be said concerning the utilization of alpha-radioactive isotopes for producing free radicals? This problem has for the moment a purely academic meaning. Alpha-radioactive isotopes are still very expensive and the production of short-life substances of this type in larger quantities is far from being realized in practice.

In view of the strong absorption of alpha radiation by matter the thickness of the isotope films would have to be reduced to 10^{-4} cm. The results of calculations made in the same way as those for beta-radioactive substances lead to the values given in Table IV.

It should be noted that in the case of use of liquid hydrogen as the raw material for producing free radicals, the thickness of the absorbing film would be only about 10^{-2} cm. In this case, 1 g. ^{210}Po transmits 33 cal./sec. energy to such a film having a surface of about 900 cm.^{2}, or 100 cal./g. hydrogen/sec.

TABLE IV.—*Characteristic Data for Typical Alpha-Radioactive Isotopes.*

Isotope	Halflife, T	Maximum Energy of the Alpha Radiation, MeV.	Mass of 1 Curie, g./Curie	Density ρ, g./cm.³	Number of Curies per unit mass, Curies/g.	Energy, cal./Curie/sec.	Surface of 1 Curie,† cm.²	Energy, cal./g./sec.	Surface of 1 g.,* cm.²
^{210}Po	138 days	5·29	$2·2 \times 10^{-4}$	~ 10†	$4·5 \times 10^{3}$	$7·4 \times 10^{-3}$	$\sim 0·2$	~ 33	~ 900
^{239}Pu	24,100 years	5·24	16·1	19·7—16‡	$6·2 \times 10^{-2}$	$7·3 \times 10^{-3}$	8200	$4·5 \times 10^{-4}$	~ 510

* Layer thickness = 10^{-4} cm. † Approximate value. ‡ Value dependent upon temperature: 19·7 g./cm.³ (room temperature). 16 g./cm.³ (600° C.).

This value is about 500 times smaller than the value necessary to transform 1 g. of hydrogen completely into free radicals and here again only a negligible part of this energy would actually be utilized for breaking molecular bonds. These are the reasons why there is no sense in coming to practical conclusions concerning the solution of constructional problems (*e.g.* the necessity of using flat and wide gaps in place of pipes, etc.).

IV. USE OF RADIATION FROM NUCLEAR REACTORS

There still remains to be discussed the radiation released inside fission reactors, consisting principally of neutron beams and gamma rays. Recently-published data[6] indicate a much more favourable position than in the case of beta or alpha particles: under the influence of radiation from fission reactors ozone is formed in liquid oxygen (temperature below — 183° C.) at the rate of about 15 molecules per 100 eV. of absorbed energy. In the irradiation of liquid water, radicals H and OH are formed, but with a much smaller yield: 3–4 radicals OH/100 eV. It should be remembered, however, that in the latter case the temperature is much higher, and that the amount of energy needed to break the H–O bond is considerably greater than the energy necessary to break the O–O bond (see Table V).

It is easy to verify that the efficiency of producing free radicals by reactor radiation reaches values up to 20%. This value is large enough to consider the matter seriously.

Of course, it is not a question of utilizing a fission reactor *installed in a rocket* for the purpose of producing free radicals. We know that from over 80 to nearly 100% of the nuclear energy released in a reactor is in the form of heat, while the neutrons and gamma rays carry only a negligible part of it. That is the reason why in this case it would be of greater advantage to utilize the heat yield itself for heating the working fluid, and the production of free radicals would be without any practical value.

TABLE V.—*Dissociation Energy of Typical Covalent Bonds.*

Bond	Energy,[7] cal./g. mole	Energy, cal./g.	Energy, eV./molecule	Energy, eV./atomic M.U.
H–H	$1·03 \times 10^{5}$	$5·1 \times 10^{4}$	4·5	2·2
O–H	$1·1 \times 10^{5}$	$6·5 \times 10^{3}$	4·8	0·28
O–O	$3·5 \times 10^{4}$	$1·1 \times 10^{3}$	1·5	0·047
N–N	$2·7 \times 10^{4}$	$9·7 \times 10^{2}$	1·2	0·043

On the other hand, fission reactors could serve as sources of free radicals on the surface of Earth. In a frozen state these radicals would have sufficient life to be later utilized in a ready state for the propulsion of rockets. However, this matter requires separate discussion.

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ASTRONOMICAL MEASUREMENTS WITH ROCKETS, SATELLITES AND BALLOONS*

By A. P. WILLMORE,† B.Sc., Ph.D.

ABSTRACT

Developments in high-altitude astronomy during the last decade are reviewed.

HIGH-ALTITUDE astronomy, that is to say astronomical observations carried out from a greater altitude than 20 km., started in the United States in 1947 with studies of ultra-violet radiation from the Sun using V.2 rockets. The subject has developed somewhat since then but only a fraction of its potentialities has been explored.

The earth-bound astronomer is severely restricted in making observations by the Earth's atmosphere. To get this into perspective, one has to remember that almost all our knowledge of extra-terrestrial bodies has been gained from observations of the electromagnetic waves, generally visible light waves, which they emit, reflect or absorb. Cosmic rays, the corpuscular radiation which bombards the Earth from the Sun and elsewhere in the universe, seems at present rather to present the astrophysicist with an additional problem to solve than to provide him with much new information. Thus the effect of the Earth's atmosphere on the electromagnetic waves that are incident upon it is of paramount importance.

Unfortunately, the atmosphere is very selective in transmitting light, most of what is incident being absorbed on the way down, or reflected. This is illustrated in Fig. 1,

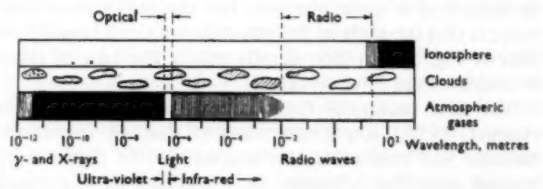

FIG. 1. Penetration of clouds and the atmosphere by radiation of different wavelengths. Only in the very small range of the visible spectrum and a somewhat larger part of the radio spectrum can radiation reach the ground without great absorption

which shows the parts of the useful electromagnetic spectrum which are able to penetrate the atmosphere to ground level. The atmosphere is in fact transparent only to a tiny patch corresponding to visible light, and a larger one lying between atmospheric absorption at the short wave end and ionospheric reflection at the other, which corresponds to centimetre- and metre-wavelength radio waves. The reason for the great importance of radio astronomy is immediately apparent in the great extension of the useful spectrum which it makes possible. The 21-cm. radiation which is picked up from interstellar clouds of atomic hydrogen comes in near the top end of the window.

The central shaded patch corresponds to infra-red or heat waves; the atmosphere is not really opaque here. A good deal of important work has been done in this region on the absorption of light in the atmospheres of the planets. This is the source of our knowledge of the constitution of the planetary atmospheres.

The radiation from hot stars, which are particularly interesting in studying the evolution of stars, lies much farther up the spectrum in the ultra-violet and soft X-ray regions. Clearly one can expect large rewards from opening up this really opaque patch. The only way in which this can be done is to make observations from a great enough height to ensure that these waves have not suffered appreciable absorption. Fig. 2 shows the height to which radiation in this part of the spectrum will penetrate, in fact, the height at which it is about two-thirds absorbed. Clearly one has to go to 100 or

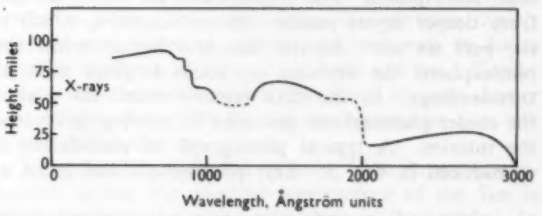

FIG. 2. Penetration depths of radiation in the ultra-violet. The height indicated by the curve is that at which approximately two-thirds of the radiation incident on the atmosphere is absorbed. In the dotted parts of the curve only the general trend is shown, the detailed behaviour being more complicated

150 km. before one can see through the atmosphere at these wavelengths, which means that the telescope must be mounted in a rocket or a satellite.

Atmospheric absorption is, however, not the astronomer's only problem. The fineness of detail which can be seen on, say, the surface of the Sun, is limited not by the quality of the best telescopes that have been built,

* Abridged version of paper read to the Society in London, 1 November, 1958.

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but by distortion introduced by the atmosphere. We have seen that the absorption occurs at some considerable height in the atmosphere in the auroral and ionosphere regions. The problem of "seeing" is connected with the atmosphere much lower down, in the vicinity of the tropopause at 10 km. The atmosphere here is turbulent, or in other words broken up by small eddies a foot or so in diameter. These produce two effects. The first is due to diffraction of the starlight passing through the troposphere, and is the ordinary twinkling of a star. This is bothersome to the astronomer only for rather special observations.

The other effect requires a good telescope to see. If you look at the image of a star under high magnification, you find that instead of appearing still it dances incessantly up and down. This is caused by variable refraction, or bending, of the rays from the star. Naturally, if the star or an extended object such as the Sun is photographed, it comes out a little blurred because of this. The effect is somewhat similar to the shimmering you see over a hot road in the summer. This problem is more easily overcome than that of atmospheric absorption because it occurs lower down, and a balloon reaching 30 km. is quite an adequate solution.

One important problem which has been tackled in this way is granulation on the Sun's surface. When seen in a telescope under high magnification, the surface of the Sun is found to be generally speckled, and this is particularly marked in the vicinity of a sunspot. This speckling is thought to be caused by turbulence in the solar atmosphere. The bright grains are where hot gas from deeper layers reaches the photosphere, which is the part we see. As the Sun gets hotter below the photosphere, the uprising gas looks brighter than its surroundings. In the dark regions round the grains, the cooler photospheric gas must be moving down into the interior. A typical photograph of granulation is reproduced in Fig. 3. This photograph was taken at the Meudon Observatory in 1887 by Jules Janssen. The effect of the atmosphere is clearly visible in the irregular blurring and distortion of the photograph. Janssen decided that he could clearly see grains with a diameter of two seconds of arc—say, 900 miles across—but he concluded also that the size of a typical grain was $\frac{1}{2}$–$\frac{1}{3}$ sec. of arc.

FIG. 3. A typical photograph of the Sun's surface taken at ground level. The patches of blurring and distortion are caused by turbulence in the atmosphere

No real ground was made in this problem until 1957, when under the direction of Spitzer and Schwarzschild of the Princeton University Observatory, high resolution photographs of granulation were obtained with a 12-in. reflecting telescope in a balloon at 27 km. altitude. Fig. 4 is one of their photographs. The improvement

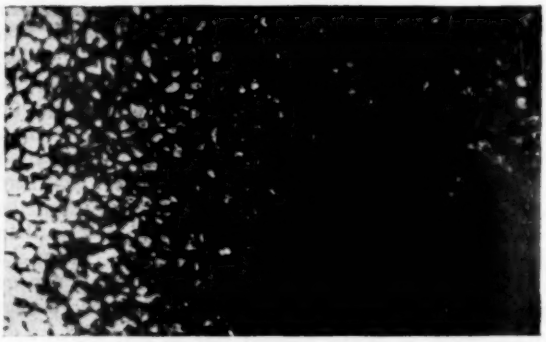

FIG. 4. A photograph of the Sun's surface taken from a balloon. The scale of this photograph is several times larger than that of Fig. 3

in definition is quite obvious, but the really significant point is that the scale of this photo is five times larger than that of Fig. 3. In fact, details only a few tens of miles in diameter are now visible.

The first successful flight of this equipment was in August, 1957. Experience showed that an unmanned balloon was preferable, on account of the disturbance caused near the telescope by observers in a manned balloon. Accordingly, the telescope was made automatic in operation. The balloon used was a Skyhook, a rather large affair 200 ft. long.

The objective of the telescope was a 12-in. diameter, f/8 paraboloid, used with a secondary mirror and an enlarging lens system, the image being photographed with a cine-camera. The diameter of the image of the Sun's disc was 2 ft., so that it could not all be photographed at once and the secondary mirror was therefore arranged to scan the telescope's field. As the temperature that the telescope would reach was somewhat uncertain, it could not be focussed before the flight, so the focussing was changed in steps between successive scans.

It was of course necessary to provide some means of keeping the telescope pointing at the Sun during the flight. This was done by arranging pairs of photocells looking at the Sun in such a way that if one cell received more light than the other, the telescope was moved back

in correction. When the telescope was changed in azimuth, the carriage and balloon tended to rotate in the opposite direction and in order to prevent this additional inertia was provided by a rotating flywheel, driven by an electric motor which was powered by storage batteries. For rotation about the other axis, the inertia of the carriage was sufficient.

Those experiments have opened up a field for high definition astronomy not only of the solar surface, but also of planetary detail and nebulae structure. Moreover, more sophisticated spectroscopic observations will be of great value in understanding, for example, the dynamics of the Sun's atmosphere. A balloon has the advantage over a rocket for such experiments of providing a flight duration of a few hours rather than a few minutes, and also of providing a more stable platform for the telescope (this is true at least of the kind of rocket ordinarily employed for research purposes). A satellite is undoubtedly a superior vehicle to either, but the technical difficulties are obviously considerable though not insurmountable.

The problem of extending telescopic observations into the ultra-violet by means of rocket flights is only just now being tackled. At a recent meeting in Moscow of scientists from countries participating in the I.G.Y., it was announced that photographs of the sky in the ultra-violet had been obtained in the United States. One suspects that the potentialities of ultra-violet astronomy hardly rival those of radio astronomy; nevertheless, these observations should significantly improve our knowledge of hot stars. An interesting and relatively simple extension of ultra-violet photography would be the use of objective prisms or gratings to obtain low dispersion spectra of stars.

However, there is one star, the Sun, which has already been extensively studied during rocket flights. Most of the advances here also have come from the United States, much work having been done in the early stages of the high altitude research programme using German V.2's. A wide variety of techniques has been used and has resulted in a fairly good knowledge being gained of the spectrum of the Sun in the ultra-violet and X-ray regions. We know a good deal more about the Sun in consequence, but there are still many important questions unanswered. The bridge between the X-ray region and the ultra-violet is not yet complete. For some time, X-ray observations, admittedly of rather a crude character, have been made at wavelengths up to 100 Å., whilst the ultra-violet spectrum has been extended to just below 1000 Å. The intervening region requires very difficult techniques, but will undoubtedly be profitable to study since it includes important coronal emissions.

The rocket observations have suffered from another significant limitation: they have all been gross studies of the solar emission. In other words, the average radiation from the Sun's disc has been measured. In order to unravel the structure of the solar atmosphere, one has to have some idea where the radiation comes from, the relative amounts coming from limb and disc. When the Sun is disturbed, it is also necessary to know where the extra radiation comes from; for example, it is important to study the radiation coming from the vicinity of a solar flare.

The extension (at great heights) of the violet end of the spectrum to shorter wavelengths is illustrated in Fig. 5. This shows a series of spectra obtained in a

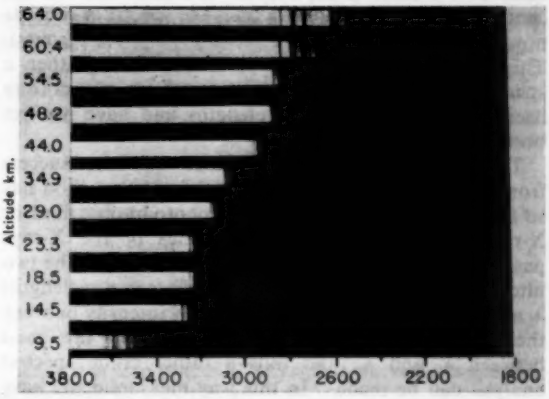

FIG. 5. Spectra of the Sun in the ultra-violet taken at different heights above the Earth from a rocket. The rapid extension of the short wavelength limit of the spectrum with increasing height once the ozone layer is passed, is clearly shown.

fairly conventional manner during a rocket flight. No great extension of the spectrum occurs until the ozone layer has been traversed at about 35 km., because the atmospheric absorption in this region is due to the ozone content. Above the ozone layer, the spectrum rapidly extends with increasing height and continues to do so steadily up to a height of at least 150 km. Similar spectra have been obtained and analysed down to shorter wavelengths than 1000 Å., and work going on now will extend still further.

The principal conclusion resulting from these measuremeants is that the effective temperature of the Sun is much lower in the ultra-violet than in the visible. In the visible part of the spectrum the Sun radiates as though its temperature were 5700° C. Now we know that the corona, the outermost part of the Sun's atmosphere, and the core, are each far hotter than this, and that this temperature refers to a relatively cold blanket round the sun, called the photosphere, which coincides with the visible disc. We know also that the temperature must continue to fall somewhat above the photosphere, since the visible spectrum of the sun is crossed by dark lines—the well-known Fraunhofer lines—which must correspond to absorption of light from the photosphere by cooler gas lying above it. Moreover the Sun's atmosphere, like all atmospheres, must become less dense with increasing heights, so the gas above the photosphere will also be relatively rarefied. Thus the falling temperature as the ultra-violet is approached is characteristic of the light coming from greater heights in the solar atmosphere. The magnitude of the change

is that the temperature falls steadily from 5700° C. at 3000 Å., to about 4500° C. at 2000 Å., the radiation intensity at the latter wavelength being only 5% of that to be expected from a temperature of 5700°C. At shorter wavelengths, below 2090Å., a change in the character of the spectrum occurs which supports the conclusion that this radiation comes from higher levels. Instead of the familiar spectrum of continuous emission crossed with dark absorption lines the spectrum consists now of bright lines on a relatively faint background. This is characteristic of the radiation from rather a sparse gas. The atomic radiations from the corona itself lie at still shorter wavelengths and have not yet been resolved.

The spectrum has also been tackled with some success from the X-ray end. The most satisfactory method has so far been to measure with either photographic films or X-ray counters the relative intensities of the X-rays passing through filters of two different metals. The two filters are arranged to cut off at different wavelengths λ_1 and λ_2, so that the difference in X-ray intensity between the two filters correspond to radiation in the band between λ_1 and λ_2, and thus a rather crude spectral analysis can be made. In this way measurements have been made of the average X-ray intensity in various overlapping bands between 6 Å. and 100 Å.

The striking feature of the X-ray intensity is that, in contrast with the ultra-violet intensity, it is far higher than that to be expected for a radiator at 5700° C. On theoretical grounds one would expect the X-rays to come from the corona. The variation of X-ray intensity with wavelength suggests that it is produced in a region where the temperature is 750,000° C., which is thus identified as the coronal temperature. Quite independant observations of the visible light emitted from the corona have shown the gas there to contain atoms of metals with very large numbers—up to fifteen—of electrons stripped off. The temperature estimated to be necessary for this to occur is about 1,000,000° C., in good agreement with the X-ray measurement. A further confirmation of the coronal origin of the X-rays is obtained from the fluctuations which occur in the X-ray emission. The X-ray intensity in the 8–20 Å. band is found to vary over a range of 100 : 1. Routine observations are made of one of the visible emissions of the corona—the 6701 Å. line of Ni XV—and the intensity variation of the X-rays and visible light can be compared. They are found to show a close correlation, both emissions being bright at the same time. This is at least evidence that the origins of the two radiations are closely linked.

It is hoped that the X-ray spectrum will be revealed in somewhat greater detail by an experiment now being developed at University College, London, for flight in Skylark rockets. A system of filters will here be dispensed with and proportional X-ray counters (with which the X-ray energies can be directly measured) used instead.

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CORRESPONDENCE

(In these letters to the Editor, some passages have necessarily been omitted)

Electrical Theory of Gravity

SIR,

In their recent letter,[1] Mr. D. J. Cashmore and Mr. C. N. Gordon suggest an interesting conflict between observation and the electrical theory of gravitation as proposed by Dr. Ba Hli.[2] One may find that the conflict is not present upon further contemplation, however.

Coulomb's law for the electrostatic force between two charged bodies separated by a dielectric medium is correctly quoted. It is understood that a substance capable of acting as a dielectric medium, such as water, does so only in the presence of a Net Electric Field. The field is necessary to cause the polar water molecules to line up, resulting in an overall reduction of the electrostatic forces between the charges responsible for the field. Now the "Net Attractive Force" of Dr. Ba Hli's theory should not be confused with a Net Electric Field. Since, in the case of a gravitational field, the two bodies are electrically neutral and cannot induce a charge on to a third body, as was pointed out by Dr. Ba Hli, the randomly directed water molecules would not be disturbed either, and the electrostatic forces would remain the same. A similar argument follows for other dielectrics. It would thus appear that the "Net Attractive Force" retains the characteristics of the gravitational force in this respect.

It is interesting to note the experimental difficulty that would be encountered in verifying Dr. Ba Hli's theory. If a number of electrons equal to the number already in a body could be added to the body, the weight would of course increase by one-half the original weight if the theory is correct. It can be shown that the change in weight of a sphere of radius R metres, when charged to a voltage V, is given by:

$$\Delta W = VZR^2/eKAN$$

where Z is the atomic weight of the material of which the sphere is made, A is the atomic number, e is the charge of the electron in coulombs, N is Avogadro's number, and K is equal to $1{\cdot}8 \times 10^{10}$. This means that if the 30 cm.-radius aluminium sphere of a Van de Graaff generator could be charged positively to a

potential of 1,000,000 volts, it would decrease in weight by only $1{\cdot}08 \times 10^{-10}$ gramme.

Respectfully yours,

LARRY E. JOHNSON.

3 Ames Street Box 463,
Massachusetts Institute of Technology,
Cambridge 39, Massachusetts, U.S.A.

31 *March*, 1959

REFERENCES

1. D. J. Cashmore and C. N. Gordon, *J.B.I.S.*, 1957–58, **16**, 586.
2. F. Ba. Hli, *ibid.*, 540.

SIR,

With reference to the letter[1] on "Electrical Theory of Gravity," it is true that the gravitational force is independent of dielectric constant, whereas the electrical force between two like charges or between two unlike charges is dependent on dielectric constant. However, the Electrical Theory of Gravity is not undermined by this fact, because the Net Attractive Force (Electrical)—called *NAF* (*E*) for short in my previous letter[2]—is independent of dielectric constant, though it is the difference between the electrical force of attraction and the electrical force of repulsion. The explanation of this independence is as follows.

The electrical force between two charges e_1 e_2 separated by a distance r in a medium of dielectric constant k, is given by Coulomb's Law

$$F_e = \frac{e_1\ e_2}{kr^2}$$

Now the variation of this force F_e with different media is due to the difference in polarization of the molecules making up that medium.[3] If we take the example of a medium such as water, which was mentioned in the Reference (1), its molecules are polar, that is, the positive and negative charges are not at the centre of the molecule but are separated from each other, giving each molecule a permanent dipole moment.

When an external electrical field E is applied, the dipoles line up in the direction of this field, since this is the position of stable equilibrium and in this case the sum of the dipole moments of the water molecules is not zero. This dipole field opposes the inducing field with a consequent reduction in the resultant electric field intensity relative to its value in the absence of the dielectric.[4] Therefore F_e depends on k.

Actually, the thermal motion of the molecules prevents them from lining up completely, by causing random orientations. Thus k decreases with increasing temperature.

When we consider the gravitational case we find that there is one basic difference from the above situation and this is that the two bodies between which the gravitational force

$$F_g = \frac{m_1\ m_2}{r^2}$$

exists, are electrically neutral. Therefore these two bodies do not cause the molecules of water to line up in any particular direction. In other words, the orientation of the molecular dipoles is random and the average dipole moment of the medium in this case is zero, just as in the case of a vacuum. Hence the force of electrical attraction between the unlike charges contained within the two neutral bodies and the force of electrical repulsion between the like charges contained within the two neutral bodies are the same as for a vacuum, $k = 1$ (see Fig. 1). The difference between them, which is *NAF* (*E*), consequently appears as for $k = 1$ whatever the medium between the two bodies.

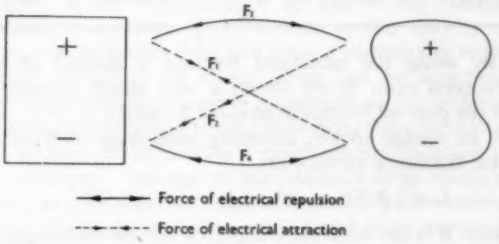

FIG. 1.

Thus it is seen that *NAF* (*E*) shows the same properties as the force of gravitation.

FREDDY BA HLI,
Director of Research.

Union of Burma Applied Research Institute,
Kanbe, Rangoon, Burma.

18 *May*, 1959.

REFERENCES

1. D. J. Cashmore and C. N. Gordon, *J.B.I.S.*, 1957–58, **16**, 586.
2. F. Ba Hli, *ibid.*, 540.
3. F. W. Sears, "Electricity and Magnetism." **1946**: Cambridge, Mass. (Addison Wesley Press).
4. N. H. Frank, "Introduction to Electricity and Optics." **1950**: New York (McGraw-Hill). The chapter on Dielectrics gives the relation between polarization and dielectric constant.

Design of Step Rockets

SIR,

I was especially interested in Mr. Vertregt's letter,[1] as I had recently dealt with the same problem, but in a slightly different way.

For a loaded rocket of mass M, propellent fM, structure σM, and payload lM, we have:

$$fM + \sigma M + lM = M \quad .. \quad .. \quad .. \quad (1)$$

and call f, σ and l the fractional parameters of the rocket. It should be noted that σ is not the same as $1/S$, where S is the structural ratio. In fact, by definition

$$\frac{1}{S} = \frac{\sigma}{f+\sigma}$$

but $f + \sigma \not\equiv 1$, unless $l = 0$.

It would seem unrealistic to assume S to be constant for a rocket, for its definition makes it independent of l. We shall see that l may be as much as one-third of f (see Table I), and cannot be neglected in the design of the structure.

TABLE I

$\sigma = 0{\cdot}07 \quad R = 44{\cdot}7 \quad V = 9{\cdot}5$ km./sec.

n	$R^{-1/n} = \sigma + l$	l	$L = l^n$	$1/L = P$
1·0	0·0224	—	—	—
1·5	0·0794	0·0094	0·00091	1099·0
2·0	0·1496	0·0796	0·00633	157·9
2·5	0·2187	0·1487	0·00853	117·3
3·0	0·2818	0·2118	0·00950	105·2
3·5	0·3377	0·2677	0·00993	100·8
4·0	0·3867	0·3167	0·01006	99·4
5·0	0·4677	0·3977	0·00995	100·5

By using the structural fraction σ instead of the structural ratio S, we obtain a very simple expression for the over-all fractional payload L (with $L = l^n = 1/P$) for an n-stage rocket, assuming each stage to have the same fractional parameters:

$$L = (R^{-1/n} - \sigma)^n \quad .. \quad .. \quad .. \quad .. \quad (2)$$

where R is the mass ratio required for the contemplated mission (for $R^{-1/n} = r^{-1} = 1 - f = l + \sigma$, and (2) becomes $L = l^n$).

Using Mr. Vertregt's values, $R = 44{\cdot}7$, $V = 9{\cdot}5$, $c = 2{\cdot}5$, for a satellite launching, we can plot L as a function of n for various σ. This has been done and the curves (see Fig. 1) illustrate several interesting facts:

(1) The German V.2 rocket, father of them all, shows up extremely poorly. It could not be orbited in less than a three-stage complex, and then only with zero payload.

Assuming a series of scaled V.2's, the most efficient satellite launcher would have six stages and would deliver 0·0005 of its all-up mass into orbit. That is, n = 6, $L = 0{\cdot}0005$, $P = 2000$.

(2) The Viking, of Vanguard fame, is much better, and is at peak efficiency with five stages. Overall payload ratio is about 309, but this figure is not realized in a Vanguard launching, partly because only three stages are used, but mostly because the upper stages are not scaled-down Vikings, but are lower performance rockets.

(3) The structural ratio of the Atlas is approximately 14, far above the value of 5 chosen by Mr. Vertregt. Its delicate structure enables it to orbit with only one-and-one-half stages (as it has done), but with a tiny fractional payload of only 0·0009.

The same basic vehicle with an added stage of equal performance could orbit a handsome 0·0085 overall fractional payload.

(4) Three-stage satellite launchers can be considered obsolescent. A three-stage, Atlas-type rocket could launch 0·0095 overall fractional payload, only 12% more than the much simpler and more reliable two-and-a-half stage arrangement.

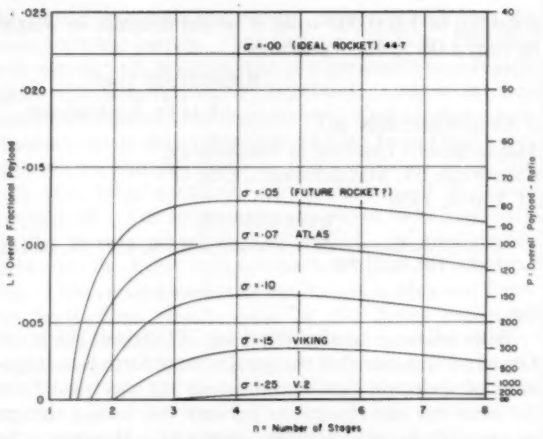

FIG. 1. The overall fractional payload, L, as a function of n, the number of stages, is plotted for certain values of σ, the fractional structural constant, for an overall mass ratio R of 44·7. Assuming an exhaust velocity, c, of 2500 m./sec., this value of R corresponds to a characteristic velocity, V of 9·5 km./sec., which, allowing for air resistance and gravity losses, is approximately that required for launching into a low altitude satellite orbit.

(5) The Discoverer series of U.S. satellites are launched by a two-stage rocket having $\sigma = 0{\cdot}07$. Therefore, $L = l^n = 0{\cdot}0063$ (see Table I). The fractional mass of the burnt-out last stage will be $\sigma l^{n-1} = 0{\cdot}0056$. The total orbiting fractional mass will be $l^n + \sigma l^{n-1} = 0{\cdot}012$.

Assuming an all-up mass of 110,000 lb., we get about 700 lb. for the net payload, about 1300 lb. for the gross mass in orbit.

(6) The unexpected brightness (and therefore size) of the Sputnik carrier rockets suggests that they were second-stage vehicles, not third-stage. In fact, a calculation based on the brightness of the orbiting rocket case assuming it to be a second stage with $\sigma = 0{\cdot}07$, leads to a maximum payload of about 3500 lb.—a figure not appreciably greater than the 3000 lb. payload of *Sputnik III*.

(7) The load curves of Fig. 1 give striking proof of the fact that propellent improvement is not the only road to success in rocketry. All the curves are calculated for $c = 2500$ m./sec., a figure that has altered little since the first V.2 lifted from its pad with $c = 2150$ m./sec.

(8) However neat and final these calculations and graphs may appear, their chief value will be to space amateurs like myself, for whom they clarify the essential features of uniform rocket staging, and make comprehensible the fragmentary and sometimes confused reports we hear of satellite launchings. Professional rocket engineers will always find it necessary to make detailed

calculations for each piece of hardware they intend to fly.

Yours truly,

P. E. ARGYLE.

4881 West Saanich Road, Royal Oak,
British Columbia, Canada.
5 *May*, 1959.

REFERENCE

1. M. Vertregt, *J.B.I.S.*, 1959–60, **17**, 30.

Manned Navigation and Guidance in the Solar System

SIR,

There are a few observations I would like to make concerning a recent article by Cashmore and Gordon.[1]

Except in their last section, the authors assume that the object of a correctional manoeuvre is to bring a space vehicle back on its precalculated track. Such a manoeuvre would be difficult to perform and highly uneconomical. In their last section they state that "*given the present position and velocity, a prediction could be made of the errors at destination and this in turn could perhaps be used to determine the necessary navigation corrections at any given time.*" I devised such a mode of correction some years ago and the results were published in this *Journal*.[2] I pointed out that when it is discovered that the ship is not on course a new situation arises and a fresh optimal track to the destination planet should be computed. The method by which the velocity increment necessary to place the ship in this new orbit could be calculated was then fully explained. However, this method has now been refined and generalized to the actual three-dimensional conditions of the problem and will be published in due course. Knowing the position and velocity deviations of the ship, reference to previously prepared tables will yield the correction to be made. Since the new optimal track will be close to the old, the effects of all small perturbing forces will be sensibly identical for both. It now follows that the *divergence* of the new track from the old is independent of these forces. But any correctional manoeuvre depends only upon this divergence and hence its computation can be made quite independent of all perturbations, and in fact may be based upon an interplanetary trajectory computed as a succession of two-body problems. Nevertheless, the tables so computed will give high accuracy when applied to observed divergences from a pre-calculated track which has been accurately determined by making allowance for every possible source of perturbation. Information contained in such tables could be conveniently stored in a computer programmed to give the velocity correction immediately a divergence is observed. It is important to appreciate that this type of correctional manoeuvre does not require a fresh predicted track to be computed *ab initio* as visualized by Cashmore and Gordon in their article.

Again, the authors state that "*the precomputation of the predicted trajectory will also involve detailed knowledge of the positions of the members of the solar system throughout the (future) period of the journey.*" I think that the accuracy to which it is worth while computing this trajectory should be thoroughly investigated. There is a tendency to assume that the methods employed by astronomers in celestial mechanics can appropriately be used in the new field of astronautical navigation. This is not obvious. Thus, consider the optimal interplanetary trajectory connecting the orbits of the Earth and Mars. I calculate that a vehicle following this track will be displaced in position by the attraction of Jupiter a distance of the order of 5×10^4 km. at the Martian terminus. An error of 1·5 m./sec. in the velocity of entry into the transit orbit will cause a comparable error. Unless, therefore, the motor thrust can be accurately controlled to deliver velocity increments to this order of accuracy, it is pointless to take these perturbing influences into account when making a preliminary calculation of the trajectory. Because of the relatively large effects at the destination planet of small errors in early correctional thrusts, unless these can be applied with great accuracy, it will be necessary to confine ourselves to the removal of gross errors alone during the early part of the voyage and to delay the removal of errors due to minor influences until the final phase of the journey. It would be folly to attempt to eliminate a small error at the risk of introducing a larger one. For the removal of gross errors, an approximate reference trajectory only is needed. Over the final phase, accurate prediction of the motion can be achieved without taking into account small perturbing influences, since these have only a long term effect. Either way an accurately-computed overall trajectory might never be employed.

Again, consider an escape manoeuvre carried out from a close orbit about the Earth. I calculate that, if the Sun's field is neglected, when the vehicle has receded to a distance of 10^6 km. from the Earth's centre, the error in position is about 700 km. and in velocity about 7 m./sec. In view of the relatively large thrust which must be applied to achieve escape, I would expect these errors to be swamped by errors due to inaccurate control of the motor thrust. No purpose would appear to be served, therefore, by an accurate computation of the escape manoeuvre taking account of perturbations due to the Sun and Moon.

The essential point is that the accuracy of a preliminary computation of a vehicle's track is related to the accuracy with which correctional manoeuvres can be performed. I feel that this relationship requires detailed investigation before we rush to our electronic computers.

Yours truly,

DEREK F. LAWDEN.

Department of Mathematics,
University of Canterbury,
P.O. Box 1471, Christchurch, C.1,
New Zealand.
15 *July*, 1959

REFERENCES

1. D. J. Cashmore and C. S. Gordon, *J.B.I.S.*, 1959-60, **17**, 46.
2. D. F. Lawden, *ibid.*, 1954, **13**, 215.

FOURTEENTH ANNUAL GENERAL MEETING

The Fourteenth Annual General Meeting of the British Interplanetary Society was held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on Friday, 17 July, 1959.

Present:

Dr. L. R. Shepherd (*Chairman of the Council*) in the Chair
L. J. Carter (*Secretary*)
and about twelve other members of the Society.

The Secretary read the notice convening the meeting which had been printed in the April issue of the *Journal*.

Chairman's Address

Dr. L. R. SHEPHERD said that owing to the printing dispute his Address (printed on pp. 102–104 of the August issue of the *Journal*) had not been circulated to members. He therefore summarized its contents. Dr. Shepherd said additionally that the number of delegates to the forthcoming I.A.F. Congress (about 500) had not escaped the notice of other authoritative bodies in this field, and after the Congress was over we would probably have scored a major victory by achieving a measure of recognition which we would not otherwise have obtained. The Society now faced an active period of expansion, but our overall pre-occupation was with financial considerations, as these seriously impeded our growth.

Annual Statement of Accounts and Balance Sheet

The SECRETARY, in presenting the accounts and balance sheet for 1958 (see p. 62 of the April issue of the *Journal*), pointed out that the previous year's deficit had been converted into a profit of about £640, mainly because of a new source of income bringing in nearly £1000 from royalties, but that this was a non-recurring source. Our costs were increasing all the time. There had been a generous response to the Benevolent Fund appeal.

Mr. C. HORSFORD asked if it was possible for ***Spaceflight*** to be sold commercially on the bookstalls.

The SECRETARY replied that taking discount and other demands into account the bookstall operators would only buy the copies at less than cost, and even then would only take a certain proportion of the number published; they appeared to regard their operations as a form of advertising for which the Society must pay. We should need something like a capital of £15,000 to launch the magazine for public sale. The only way to make it pay now was on a subscription basis.

It was then proposed by Mr. G. SAVAGE (Member) and seconded by Mr. E. HOPE-JONES that the audited accounts for the period to 31 December, 1958, be approved. This was put to the meeting and agreed *nem. con.*

Election of Members of Council

The Chairman pointed out that as just eight nominations had been received for the eight vacancies on the Council, it had not been necessary to hold a postal ballot. The nominations were as follows:

JOHN ELLISTON ALLEN, B.Sc. (Eng.), A.M.I.Mech.E., A.F.R.Ae.S., A.F.I.A.S. (Fellow).
Age 38. Head of Aerodynamics, Projects and Assessment Dept., Weapons Research Division, A. V. Roe & Co. Ltd.

MAURICE BRENNAN, B.Sc., M.I.Mech.E., F.R.Ae.S. (Fellow).
Age 45. Assistant Chief Engineer, Vickers Armstrong (Aircraft) Ltd.

ALFRED HUGH STANTON CANDLIN, B.Sc. (Tech. Chem.), Assoc.I.Mech.E. (Fellow).
Age 48.

DAVID JOHN CASHMORE, M.Sc. (Fellow).
Age 33. Senior Engineer, English Electric Aviation Ltd.

STUART WILLIAM GREENWOOD, M.Eng., A.M.I.Mech.E., A.F.R.Ae.S. (Fellow).
Age 34. Lecturer, Department of Aircraft Propulsion, College of Aeronautics.

WILLIAM RALPH MAXWELL, B.Sc., Ph.D.
Age 45. Rocket Propulsion Establishment, Ministry of Supply.

NORMAN ROBSON NICOLL (Senior Member).
Age 39. Lecturer in Design and Materials, Staffordshire County Education Authority.

ALAN EDWARD SLATER, M.A., M.R.C.S., L.R.C.P. (Fellow).
Age 64. Physician and Author.

Dr. SHEPHERD asked if anyone present had any objection to the voting being carried out for all eight nominations simultaneously. As no objection was forthcoming, Mr. E. HOPE-JONES (Fellow) then proposed that the eight nominees be elected, and this was seconded by Mr. C. HORSFORD. On being put to the vote, the proposal was carried unanimously.

Special Resolution on Grades of Membership

The Chairman asked for comments on the Special Resolution concerning an alteration in the grades of membership, but there were none from the meeting. The report of the scrutineers (Mr. E. HOPE-JONES and Mr. G. SAVAGE) on the postal ballot held on the resolution was read by the Secretary. The results were:

	FOR the Resolution	AGAINST the Resolution
Fellows	332	4
Senior Members	25	–
Members	266	8
Total	623	12

Mr. D. BUCKINGHAM (Fellow) formally proposed the adoption of the resolution. This was seconded by Mr. N. NICOLL (Senior Member), and on being put to the meeting was carried unanimously.

General Discussion of the Affairs of the Society

The CHAIRMAN said that he hoped that members would now raise any points concerning the Society.

A member asked about the present status of the Yorkshire Branch's observatory. In reply, the SECRETARY said that the Council had supported this idea before any artificial satellites had been launched, but now all our efforts had gone on our three Moonwatch teams. He had seen the Yorkshire members hard at work building the observatory dome; this had absorbed much of their initiative and there was no observing programme for the 6-in. telescope.

Mr. E. HOPE-JONES (Fellow) asked whether the Benevolent Fund officially existed yet, whether any applications had been received, and if the money would be invested.

The SECRETARY confirmed that the Fund did exist, since the Council had appointed Trustees. About £300 had been received; the fund would be invested and that was why we had asked for £3000. There had been no applications for assistance, but Mrs. R. A. Smith had received a small advance grant. However, as a general rule it would be improper to publicize the beneficiaries.

Discussing the new membership application form, Mr. HOPE-JONES said that he thought that the large space given for particulars of qualifications might put people off, but the Secretary showed a circular which is sent out with the form, and Mr. Hope-Jones was reassured by this.

Mr. HOPE-JONES also asked about the new lower age limit for membership (16). The Secretary replied that it was damaging to the Society's prestige to have small boys among the membership and that it was liable to be difficult to obtain their subscriptions.

Another question raised concerned the fact that the lending library was only open to Fellows. The SECRETARY replied that the present staff could not cope with more people coming in to use the library, particularly as they nearly always talked at great length, so that in consequence the staff had to work late to make up for lost time.

Mr. HOPE-JONES said that we would have to open up the library sooner or later, because of our status, as all other Societies had libraries available to all.

Dr. SHEPHERD pointed out that such Societies had often been left large legacies and so could afford to do this.

A member suggested that the Society should provide a reference library, where refreshments would be served. The SECRETARY replied that he would be prepared to discuss the idea with any member willing to take the task on.

Another member pointed out that the Committee recently set up by the Government did not include the names of those who had pioneered spaceflight over the years, but did include people who only a few yars ago had said that space travel was "utter bilge."

Dr. SHEPHERD said that the Council of the Society had also asked the same question; he himself was on it as a representative of the Royal Society, not of the B.I.S. It was an unsatisfactory state of affairs, but we could not force the Committee to have us on it.

There being no other business, the Annual General Meeting was ended.

NEWS AND ANNOUNCEMENTS

B.I.S. NEWS

Council, 1959-60

At the Annual General Meeting held on 17 July (reported in detail on p. 144), D. J. Cashmore, S. W. Greenwood, Dr. W. R. Maxwell and Dr. A. E. Slater were re-elected Members of the Council; J. E. Allen, M. Brennan, A. H. S. Candlin and N. R. Nicholl were elected to fill the remaining four vacancies, created by the retirement of Mr. W. N. Neat and by the increase in the number of Members of Council from twelve to fifteen.

Mr. Patrick Moore, who has been a Member of Council for many years and is also well known to the public for his books, broadcasts and television appearances on astronomical and astronautical subjects, has had to resign from the Council. His resignation was received with great regret.

Council has decided to fill the resulting vacancy by co-opting Squadron Leader M. N. Golovine, who is Managing Director of A.T.S. Co. Ltd. (a member of the Hawker Siddeley Group). We are glad to announce that Sqn. Ldr. Golovine has agreed to serve.

At a meeting of the new Council held on 3 October, Dr. L. R. Shepherd was re-elected Chairman of Council, and Mr. K. W. Gatland a Vice-Chairman. In view of the anticipated increase in the Society's activities, it was resolved that two Vice-Chairman should be appointed in future and Dr. W. R. Maxwell was elected to the other position.

Informal Groups

Members of the Society residing in the vicinity of Washington, D.C., have decided to form an Informal Group and are arranging lectures and discussions. Mr. Freeman G. Lee, 7302 Keene Mill Road, Springfield, Virginia, U.S.A., is acting as Secretary. The Group has no intention of attempting to compete with the American Rocket Society, or American Astronautical Society.

For some months past an Informal Group has also been functioning in South Shields; its Secretary is Mr. W. Devine, 145, Bambrugh Avenue, South Shields. A similar group exists in Derby, its Secretary being Mr. D. A. Wigley, 160, Manor Road, Derby.

Payment of Subscriptions

By virtue of the powers entrusted to the Council under the provision of Article 22, certain amendments have been made to the Society's Bye-Laws.

At a meeting held on 2 May, Council amended Bye-Laws 9 and 13 to read as follows:

Bye-Law 9

No member whose subscription remains unpaid after 30 June in any year shall be entitled to receive copies of publications or notices of meetings, or attend and vote at any meeting of the Society, *but he shall be liable to pay for material supplied to him up to that date.*

Bye-Law 13

In the event of resignation, lapse arising from non-payment of subscriptions, rescission of membership under the provisions of Article 12, or cessation of membership arising from any other cause, the Certificate of Membership shall be delivered up to the Society. Any member whose membership ceases in the manner specified herein shall not be entitled to the return of any monies paid by him by way of subscription, entrance fee, or voluntary contribution, *but (if his subscription remains unpaid) he shall be liable to pay for material supplied to him up to the date of such cessation of membership.*

The amendments (indicated by italics) became effective as from 30 June, 1959. Their purpose is to allow a longer time for the payment of subscriptions and to require members who wish to resign to remit for the cost of material supplied to them before their intentions were made known to the Secretary.

Corporate Membership

Another amendment to the Bye-Laws introduces the new grade of Corporate Membership, provision for this already existing in the Society's Articles. This grade is intended for industrial firms and other organizations and is subject to the following regulations:

1. Corporate Membership shall be open to industrial, scientific, educational and other organizations. The Council of the Society shall have an absolute discretion in making elections to this grade and its decision on the question of the eligibility for admission or otherwise shall be final.

2. A Corporate Member shall be entitled to nominate not more than five individuals for membership of the Society (and further individuals from time to time in place of any such nominees not being elected or ceasing to be nominated members), provided that an individual so nominated must be eligible for election as a Fellow, Associate Fellow, Senior Member or Ordinary Member and shall submit a signed application for membership and shall be subject to election by the Council in accordance with these Articles and Bye-Laws.

3. A Corporate Member shall not be qualified for election to the Council. A Corporate Member shall not be entitled to receive notice of nor attend nor vote at any General Meeting of the Society.

4. Save as may be otherwise provided, a member nominated by a Corporate Member shall have all the rights and privileges and shall be subject to the conditions appertaining to the class of membership to which he shall be admitted.

5. Save as aforesaid, during any period in which there shall be no individual member nominated by a particular Corporate Member, then such Corporate Member shall have all the rights and privileges and be subject to the conditions appertaining to an Ordinary Member.

6. A member nominated by a Corporate Member shall be entitled at any time during membership to elect by notice in writing to the Council as from the date of service of such notice to continue membership in his own right and in all respects as if he were not a nominated member.

7. All nominations by a Corporate Member and revocations of such nominations shall be made in writing under the hand of an officer duly authorized in that behalf by the Board of Directors or equivalent governing body of such Corporate Member.

8. A Corporate Member shall be entitled to such other rights and privileges as the Council shall from time to time determine.

9. The fees payable shall be in the sum of £100 per annum.

10. The privileges extended to Corporate Members shall be the following:

(*a*) Receipt of the Society's *Journal*, of *Spaceflight*, and of all other publications of the Society, *e.g.*, "Realities of Space Travel," "High Altitude and Satellite Rockets," etc.

(*b*) The Corporate Member may elect five representatives, who will receive the full benefits (including periodicals) of members of the Society.

(*c*) Corporate Members shall be entitled to use the Society's Library.

(*d*) The right to advertise in both the *Journal* and *Spaceflight* at a 25 per cent. discount on the normal prices.

(*e*) A subscription to *Astronautica Acta* and receipt of the technical papers presented at each Congress of the International Astronautical Federation.

(*f*) Corporate Members may send representatives to attend all Society meetings in this country and also to the Congresses of the International Astronautical Federation.

Library Subscription Rate

In view of the increases in printing costs which have followed on the recent dispute in the printing industry it has been found necessary to increase the library subscription rate to the Society's publications from £1 15s. to £2 10s. per annum (from $5 to $7.50). This increase will take effect immediately.

Compounded Subscription Rate

Members are reminded that it is possible to compound for all future subscriptions by payment of a single sum. By doing this, the member benefits by paying a much smaller sum that would be required in separate annual fees, particularly if it ever becomes necessary to increase the annual subscription.

The Society benefits by having the immediate use of a lump sum; these payments are invested and credited to a special account in readiness for future use in purchasing headquarters for the Society or for similar purposes.

The present compounded subscription rates are as follows:

Age	Members		Fellows, Associate Fellows and Senior Members	
	£	$	£	$
20–25	41	115	50	140
26–30	37	105	45	126
31–35	34	95	40	112
36–40	31	87	36	100
41–45	28	79	33	92
46–50	26	73	30	84
51–55	23	64	26	73
56–60	21	59	24	67
over 60	18	51	21	59

It is hoped that as many members as possible will take advantage of this method of payment.

Change in Editorial Address

The Editorial Office of the *Journal* has removed to **1, Herbert Road, Hornchurch, Essex** (Telephone: Hornchurch 40759); all material for publication should be sent there. The addresses of the Society's Headquarters and Advertisement Manager remain unchanged.

London Lecture Programme, 1960

A number of posters advertising the Society's lectures and symposia to be held during the forthcoming session are being printed. Members and others who have opportunities for displaying these on the notice boards of their works, colleges or offices, etc., may obtain them on application to the Secretary, 12, Bessborough Gardens, London, S.W.1.

Income Tax Relief for Annual Subscriptions

The Society is approved by the Commissioners of Inland Revenue for the purposes of Section 16 of the Finance Act, 1958, so that members who qualify for relief under that Section are able to claim the whole of their annual subscription as a deduction from their emoluments assessable to income tax under Schedule E, and should apply to their tax offices for form P358 on which to make a claim for adjustment of their P.A.Y.E. coding. It is not necessary to produce a receipt for the payment of the subscription.

Election of Members

The following elections were made at the Council Meeting on 4 April, 1959:

New Fellows.

ALBERT CHARLES BALLASEYUS, B.S., 10577, Ashton Avenue, Los Angeles 24, Calif., U.S.A.
DENNIS CONYERS, 20, Cransley Crescent, Henleaze, Bristol.
JOHN VINCENT CROWLEY, B.E., 18852, Plummer Street, Northridge, Calif., U.S.A.
FRANK FITZGERALD, B.Sc., 368, Barugh Green Road, Gawber, Nr. Barnsley, Lancashire.
ROBERT HENRY GOODING, M.A., 19, Abbott's Ride, Farnham, Surrey.
ROBERT JAMES GUNKEL, M.S., 316, Swarthmore Avenue, Pacific Palisades, Calif., U.S.A.
RONALD WILLIAM JOHNSON, B.Sc., A.R.I.C., 8, Richmond Court, Wykeham Road, Worthing, Sussex.
HENRY FIELDS MCKENNEY, 197, West Maryknoll, Rochester, Michigan, U.S.A.
ALFRED DAVID MOSTYN, B.Sc., 17, Elm Walk, Stevenage, Hertfordshire.

Members elected to the Fellowship.

JAMES GORDON CARROLL, B.A., B.S., 88, Valley Avenue, Martinez, Calif., U.S.A.
DENNIS HENRY STANLEY RUSSELL, Tyndale House, 7A, High Street, Chipping Sodbury, Nr. Bristol.
HARVEY ERIC JOSEPH SHIEFF, B.Sc., 13, Scotney Road, Basingstoke, Hampshire.
JOHN CHARLES STARBUCK, 32, Cyprus Street, Darwen, Lancashire.

Members elected to Senior Membership.

CHARLES ROBERTSON MILNE, 17, Grasdene Grove, Harborne, Birmingham, 17.
KENNETH JOHN SPARKE, 1, North Street, Cheddar, Somerset.
IVOR ARTHUR WALTER SUTTON, 62, Ferndale Road, Swindon, Wiltshire.

New Members.

MICHAEL GEORGE ALLEN, 20, Victoria Crescent, Parkstone, Poole, Dorset.
RICHARD RUSSELL AUSTIN, 17, Parkgate Crescent, Barnet, Hertfordshire.
FLORENTINO AYLAGAS, Moreton Hall, Weston Rhyn, Nr. Oswestry, Shropshire.
GEORGE HENRY ARMSTRONG, 11, Glenfield Road, Blackwell, Darlington.
BERNARD BRENNAN, 101, Capel Street, Dublin, Eire.
ALBERT GEORGE BRUETSCH, B.S., 671-A, Plaza Avenue, North Sacramento, 15, Calif., U.S.A.
MICHAEL ANTHONY HUGO DILLON, No. 5 Flat, 32, St. Mary's Bootham, Yorkshire.
VINCENT DINAN, 5, Osborne Road, Doncaster, Yorkshire.
NOEL GOODENOUGH, 25, Amberley Avenue, Bulkington, Nuneaton, Warwickshire.
GEORGE PHILLIP HARRIS, 3532, Herbert Street, San Diego 3, Calif., U.S.A.
JOHN JAMES HODGE, "Avonlea," Ursuline Road, Waterford, Eire.
JOHN STEPHEN HUNT, Apt. 11-D, Glen Cairn Mansion, 270, Riverside Drive, New York, 25, N.Y., U.S.A.
GEORGE PATRICK JOHN RUSHWORTH JELLICOE, D.S.O., M.C., The RIGHT HON. THE EARL JELLICOE, Brooks's Club, St. James's Street, London, S.W.1.
E. R. LANCASTER, M.A., G.E.Co., Court Street, Building 3, Room 3, Syracuse, N.Y., U.S.A.
MICHAEL JOHN LIGHT, 9 O.M.Q., R.A.F. Hospital, Nocton Hall, Nocton, Lincoln.
PETER MCGIVNEY, 5, Kingshill Avenue, Northolt, Middlesex.
ALEXANDER NYMAN, M.Sc., Bretton Road, Dover, Mass., U.S.A.
DAVID JAMES PARFITT, 151 Sqn., Signals Section, R.A.F. Leushars, Fifeshire.
ALBERT PARK, "The Bungalow," Shore road, Hesketh Bank, Nr. Preston, Lancashire.
CHARLES LESTER RATTER, P.O. 30070, Nairobi, Kenya.
WILLIAM ARNO SALMI, 9438, State Line Road, Leawood, Kansas City 15, Miss., U.S.A.
EMIL R. SHAW, Box 532, Senecaville, Ohio, U.S.A.
GEORGE GUTHRIE PETRIE THORBURN, 27, Coniston Road, Fulwood, Preston.
MARTIN JOHN LESLIE TURNER, 225, Main Road, Dovercourt, Harwich.
BARRY WELLS, 173, The Broadway, Broadstone, Dorset.

Deaths

The Council regrets to announce the deaths of:

JAMES PERCIVAL ARKELL.
RICHARD BENNETT.
L. H. COMBS.
ALFRED RICHARD WEYL.
JOSEPH ARTHUR WHALLEY.
KAZIMIERZ ZARANKIEWICZ.

OBITUARY

R. A. Smith

A Spirit gripped him by the hair and carried him far away,
Till he heard as the roar of a rain-fed ford the roar of the Milky Way:

(From *Tomlinson*, by Rudyard Kipling)

I came to know Ralph through Jack Edwards, the B.I.S. pre-war "Research Director," but my close acquaintance with him began when I joined the Society in 1936. From that time until his death my friendship with him and respect for his talents deepened, and except for about two years when Ralph was in hospital with tuberculosis during the war and my own brush with this disease in 1953–54, we saw a great deal of each other. Apart from his own family, I knew him better than anyone did, and will cherish that privilege all the rest of my life. I wish I could believe in some Interplanetary Valhalla, where astronauts, even fireside ones, would be reunited.

Ralph said that he designed his first spaceship at the age of twelve, that is, in 1917, and though this drawing does not now exist, he has left an extensive collection of line drawings and pictures covering most spheres of astronautics. Many of these illustrations are already of considerable historical interest, containing features which have since found practical embodiment in rocketry. His best illustrations are, naturally enough, of subjects which particularly intrigued him—for example, the Spacestation, the Man-carrying Rocket, and the Lunar Base. The first two of these have often been mistaken for models when reproduced in publications. And his picture of the construction of the spacestation in orbit has been used as a criterion of perspective.

All his drawings, even the most complex, were completed in a few hours, usually without preliminary sketches. Nevertheless Ralph was not satisfied with a purely artistic rendering of a subject; on the contrary, many of his pictures were not commenced until he had spent a long while in proving by calculation that what he had in mind was a reasonable engineering possibility. As a result, Ralph was pre-eminently successful in endowing theoretical and visionary concepts with engineering veracity. Certainly on one point Ralph was adamant: he refused to draw astronomical pictures which would make arresting exhibits but refuted known facts or would be optically incorrect. Indeed, his lunar landscapes are, so to speak, "taken from life."

The high degree of reality which Ralph imparted to his illustrations is then largely attributable to his mathematical and engineering competence. Though he himself lamented his lack of both, his achievements belie this self-criticism. Before the war he was principally engaged in architectural decoration. Even here computation was necessary, and afforded good grounding for such pictures as his colour painting of the interior of Lunar City. Ralph was in fact responsible for the interior décor of several famous London hotels and metropolitan and provincial super-cinemas. On one occasion he was given the task of duplicating a ceiling panel painted by a famous artist, which had become damaged beyond repair. When the new panel was in place an art expert was asked which was the replacement . . . and picked the wrong one.

Both Ralph's sons—Bryan and Ashtyn—are competent artists, each in his own manner. Bryan's studies are bright and warm with sunlight, usually with a scenic theme. Ashtyn's range from portraiture to symbolism, using a variety of techniques and remarkably rich colouring. He is also adept at whittling grotesque figurines. Ralph, though he admired Picasso and revered van Gogh, disliked some modes of modern art: for example, gruyère cheese sculptury. This, he balefully opined, was mostly better done by the wind and rain

Part of Ralph's minority was spent at St. Peter's Eaton Square Choir School, and he matriculated at Ealing County. I cannot remember any occasion when he burst into song, but he was a good performer at the piano when the fit took him, being deeply appreciative of classical music. His favourite composer was Chopin, of whose works he possessed many gramophone records.

But for recreation as distinct from relaxation Ralph liked nothing better than discussion. Being an exceptionally fast thinker, well versed in many subjects and equipped with facility, cogency and pungency of expression, his conversation was always stimulating, and on serious matters invariably merited sober consideration. He was an excellent platform-man, though once embarked on his subject time stood still for him, and there was no telling when he would finish. In private as distinct from public speaking, his feelings sometimes ran away with his words. This occasionally led him into the composition of corrosive letters, which, however, owing to fits of forgetfulness, rarely got posted. He could converse freely with three or four people at a time whilst painting or drawing, but when he was working on a problem he was lost to the world. Then, the universe extended around him no further than his reach for a cup of tea, which he expected to materialize on unspoken demand at all hours of the day or night, anywhere. He could concentrate in the midst of any amount of din, but he could not work at full pressure without tea. He put all his energies into whatever task he undertook, and never let up till it was done. He once worked three days and nights without stopping, and 5 hours of sleep was customary.

The first Headquarters of the B.I.S. after transfer from Liverpool to London, and where Jack Edwards had a flat, was at Ralph's house in South Chingford. There are still a few of us left who remember those relatively care-free days—days when even the most formal of meetings were always happily informal, and often hilarious. If for nothing else, the B.I.S. owes a debt of gratitude to Mrs. Smith for her unstinted hospitality and warm welcome to all comers. Never, then nor since, has Mrs. Smith grudged the time Ralph spent on B.I.S. affairs, even though she knew that insofar as worldly advancement for Ralph and herself was concerned the B.I.S. was a millstone.

In those days (and alas no less now) the B.I.S. was liable to swallow its officers whole and make demands on their lives which only the most incorrigible of pioneers have survived. Ralph, for example, was Organizing Secretary, Member of the Council, the Technical Committee, the Experimental Committee, and chief and unaided designer. Although the Technical Committee debated Edwards' proposals for a spaceship, it was Ralph who evolved the engineering and laid the foundation for subsequent studies.

While in hospital during the war, Ralph corresponded with members of the B.I.S. and wrote an article on a modified B.I.S. spaceship which was published in *Flight*. When fully recovered in health, he and his family came to live in High Wycombe, and Ralph resumed work as a design draughtsman in the radio tube M.A.P. shadow factory for which he had provided the layout. As I too, was working there, this brought us together again and enabled us to co-operate in several astronautical studies about which I had formulated ideas. But it was not till after the war that we really began the series which yielded the Spacestation, the "*Megaroc*" Man-carrying Rocket (submitted to the Ministry of Supply, and of course rejected), and the Spacesuit.

Many of Ralph's drawings were exhibited at the B.I.S. conversazione of 1 October, 1949, and many have achieved world publicity. In those days reporters of all shapes, sizes, degrees of intelligence and universal lack of shorthand, descended on us in rapid and embarrassing succession,

during business as well as leisure hours. It is not often, I imagine, that a reporter calls for a story and stays for bed and breakfast. That, however, was the fate of one journalist who called on Ralph and became so deeply involved in astronautics that he missed the last train back to London. The parting conversation was typical of both Fleet Street and Ralph. Said the journalist: "Would it be all right if I say that I left you seated at the piano playing a Chopin nocturne?" . . . Said Ralph: "Yes . . . except actually there are no keys in the piano!"

It was round about this time that *Pathe Pictorial* filmed Ralph and myself at work in my rooms at Loudwater. As this operation entailed festooning the house with wires and connecting extra cables to the lighting system at the junction box in the downstairs pantry, it is perhaps fortunate that my landlady was out! Some weeks later Ralph and I underwent the nerve-racking and ego-deflating experience of seeing ourselves on the screen of a local cinema. An ordeal, incidentally, not at all assuaged by the accompanying commentary.

From this time on Ralph's drawings were often used as illustrations for books, technical journals, magazines, advertisements and T.V. programmes. He also made broadcasting recordings and T.V. appearances. During one year he painted a series of 45 pictures, 8 in colour, visualizing the steps in advancing from instrument rockets to a lunar colony. These paintings, with a descriptive text by Arthur Clarke, made up the book *Exploration of the Moon* which was published in 1954 by Frederick Muller Ltd. Another year he painted a number of astronautical illustrations in colour for a *Daily Mail* Children's Annual. Between times, he gave lectures and wrote articles and chapters for various publications. He was Vice-Chairman of the B.I.S. Council from 1953 to 1956, and Chairman during 1956–57. He did yeoman service at the Rome I.A.F. Congress of 1956, and his literary skill and fine appreciation of natural and cultural beauty is well exemplified by his *Journal* report of that visit. For Ralph, "the earth and common face of Nature," did indeed speak "rememberable things."

Ralph played a major part in framing the B.I.S. pre-war Constitution when Headquarters moved to London. After the war he was active in promoting fusion with the C.B.A.S and was one of the ten original Guarantors of the reconstituted Society. But his main interest lay not in organization but in practical experimentation. During his long friendship with Jack Edwards, from schooldays till Edwards dropped out of the B.I.S. during the war, he was almost continually engaged in designing and helping to make gear for Jack's inventions. Naturally enough, then, Ralph was strongly in favour of the B.I.S. experimental programme; indeed he drew plans (which still exist) for a rocket motor test stand. But the pre-war B.I.S. never had enough money to make experimental headway, and in any case war intervened to suspend activities. However, post-war Governmental interest in rocketry gave Ralph an opportunity to work on rockets, and he obtained a post in the Drawing Office at Westcott, where for some years he was a Leading Draughtsman concerned with the development of rocket power plants and associated equipment. I believe that some of Ralph's happiest years were spent at Westcott; but the remuneration was low compared with that for similar work with industrial concerns; moreover, the fact that design was moving towards the production of missiles, with which he did not want to be associated, forced Ralph ultimately to resign and take the post of Senior Chief Designer with the firm of I.V. Pressure Controllers, later moving house from High Wycombe to Rickmansworth.

In August 1958, and without warning, Ralph suffered the stroke from which he did not fully recover. Indeed, he did not return to work, and in January 1959, developd coronary thrombosis, finally succumbing on 14 February to cardiac failure, whilst under treatment in Harefield Hospital. It was with a heart no less heavy than any of his family that I attended his cremation at Ruislip. Here, among the floral offerings lay a sheaf bearing the inscription—"*In Tribute to R. A. Smith, a Pioneer of Astronautics, from the Council of the British Interplanetary Society.*" I am sure that Ralph would have been pleased with this acknowledgement of his services to the subject which engrossed his life and sapped so much of his energies. He did not live to see space crossed, but his contributions to the advancement of the B.I.S. and astronautical conceptions were manifold, and will not be forgotten. Under more auspicious circumstances his contributions to astronautics would certainly have been greater, and more satisfying to himself. However, part of himself lives on in the person of his son Ashtyn, who follows in his footsteps, who has worked on the electronics associated with the successful British high-altitude research rocket *Black Knight*, and who may well live to see his father's dream, the crossing of space, fulfilled.

H. E. Ross.

JOINT ACTIVITIES

Eleventh International Astronautical Congress

The Eleventh Astronautical Congress, which is being organized by Svenska Interplanetariska Sällskapet (the Swedish Interplanetary Society), will be held in Stockholm during the week 15-20 August, 1960. This will be along the same lines as the Tenth Congress, held in London this year under the aegis of the B.I.S. An attendance of several hundred is expected, including delegates from all the principal astronautical societies throughout the world. During the course of the Congress the business and committee meetings of the International Astronautical Federation will be held and there will be lecture sessions and various social activities.

The address of the Secretariat for the Congress is: I.A.F.-60, Box 5045, Stockholm 5, Sweden. Persons and organizations wishing to receive further information concerning the Congress are invited to write there.

The main sessions of the Congress will take place at the Royal Institute of Technology (Kungl. Tekniska Högskolan), Stockholm. The papers presented will not be restricted to a single theme, but will cover a wide range of subjects falling mainly within the following sections:

B. Basic Sciences.

A. Planetary Atmosphere Environments.
Basic atmospheric properties.
Physical and chemical problems of interplanetary flight (*e.g.*, re-entry).

I. Interplanetary Space.
Interplanetary matter and radiation.
Planetary magnetic fields, particle belts, etc.

M. Space Medicine and Biology.
Physiological and psychological aspects of life in extraterrestrial environments.

T. Trajectories.
Powered and free flight in space and within planetary atmospheres.

N. Navigation, Guidance and Control; Space Communications.

P. Propulsion.
Present and future systems.

V. Vehicles.
General systems concepts, subsystems, structures, materials, equipment, power supply, assembly in space, etc.

S. Space Probes, Satellites, and High Altitude Rockets.
Specified projects: description and presentation of results.

E. Economic Factors.
Economics and planning of space research, technology and development.

Lectures not falling within any of the above fields can be accepted for a special session.

A preliminary proposal is under consideration concerning a special Space Medicine Symposium to be held during the Congress but independent of Section M above. It is also proposed that a separate Space Law Colloquium should be held on one of the days during the Congress. When definite plans have been drawn up a further announcement will be made.

The total number of papers to be presented (in parallel sessions) will be limited to sixty-five. This number does not include papers to be read at the Space Medicine and Space Law meetings, if these are held.

All papers must be original contributions that have not been published in any form prior to the Congress, and must be of an internationally accepted standard. They may be written and presented in one of the official languages of the International Astronautical Federation (English, French, German and Russian), but it is recommended that English should be used if possible. The manuscripts in final form for presentation and publication must be in the hands of the Congress organizers not later than **15 May, 1960**, together with an approved summary in English (500-1000 words). This deadline has been fixed because it is hoped to have available at the Inauguration of the Congress a duplicated volume containing all the papers and English summaries.

However, in exceptional cases papers submitted after the deadline can be included in the Congress Programme, providing they include new and valuable information that could not possibly have been available at that date.

Prospective authors are invited to submit papers for presentation through the regional screening committees set up by the Member-Societies of the I.A.F. Each author is asked to notify the Chairman of the appropriate Committee of his intention to submit a paper and should accompany this notification with a provisional title. Final dates for submission of abstracts and manuscripts will be announced later, but it would be appreciated if those members of the Society who are considering writing a paper would immediately notify the Chairman of the I.A.F. Committee (Dr. L. R. Shepherd, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1) of the proposed title. If possible, a short synopsis should also be enclosed. These should be received not later than **31 January, 1960.**

Lecture on Test Bed Design

The British Interplanetary Society and the London Section of the Institution of Plant Engineers are holding a Joint Meeting on Tuesday, 23 February 1960, at the Royal Society of Arts, John Adam Street, London, W.C.2, at 7 p.m. R. H. B. Forster and L. Breen will present a paper on "Some Problems Encountered in the Design of Large Rocket Test Beds."

PERSONAL NOTES

Mr. S. W. GREENWOOD (MEMBER OF COUNCIL) has left the staff of the College of Aeronautics and is now engaged as an aeronautical consultant and author.

DIARY

The Society

9 January 1960. Film Show (Lecture Theatre, Science Museum, Exhibition Road, South Kensington, London, S.W.7 at 7 p.m.).

16 January. Schools Lecture. "The Scientific Exploration of Space," by Dr. N. H. Langton. (Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, at 3 p.m.). (Tickets required.)

2 February. "The Use of Reinforced Plastics in Rockets," by A. Wilson (Lancaster Room, Caxton Hall, Caxton Street, London, S.W.1, at 7 p.m.).

23 February. Joint Meeting with the London Branch of the Institution of Plant Engineers. "Some Problems Encountered in the Design of Large Rocket Test Beds," by R. H. B. Forster and L. Breen (Royal Society of Arts, John Adam Street, London, W.C.2, at 7 p.m.).

5 March. Symposium on "The Exploration of the Moon." "1. Description of the Moon," by Patrick Moore. "2. Unmanned Exploration of the Moon," by K. W. Gatland. "3. Manned Exploration of the Moon," by W. N. Neat (Lancaster Room, Caxton Hall, Caxton Street, London, S.W.1, at 2.30 p.m.).

7 April. "Lunar Missions and Vehicle Design," by J. Allen (Tudor Room, Caxton Hall, Caxton Street, London, S.W.1, at 7 p.m.).

28 April. "High Altitude Chambers and Pressure Suits," by Dr. E. W. Still (Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, at 7 p.m.).

6 May. Visit to de Havilland Engine Co. Ltd., Hatfield, Herts. (Tickets required.)

ASTRONAUTICAL ABSTRACTS

Edited by J. HUMPHRIES and J. FOLEY

1959–60 PART 5

A list of abbreviations of titles of journals was included with the 1954 index and addenda have been published in subsequent issues of the *Journal*. A further addendum is given below:

A.I.R. Boll.	Associazione Italiana Razzi Bollettino.
Army, Navy, Air Force J.	Army, Navy, Air Force Journal.
Brit. Med. J.	British Medical Journal.
Canad. Serv. Med. J.	Canadian Services Medical Journal.
Jap. Saf. Forces Med. J.	Japanese Safety Forces Medical Journal.
Mendel Bull.	Mendel Bulletin.
Univ. Calif. Radiation Lab.	University of California Radiation Laboratory.
W. Va. Med. J.	West Virginia Medical Journal.

2—PHYSICS

[*See also* abstract no. 774.]

.1 *General*

(670) **Rocket and satellite studies during the I.G.Y.** J. Kaplan. *Aero. Engng. Rev.*, **15** (4), 64–7 (*April*, 1956).

.5 *Heat and Thermodynamics*

(671) **Thermal design of large storage vessels for liquid hydrogen and helium.** R. B. Scott. *J. Res. Nat. Bur. Stand., Wash.*, **58**, 317–25 (*June*, 1957). (8 *refs.*)

(672) **Mass-transfer cooling of a laminar boundary layer by injection of a light-weight foreign gas.** E. R. G. Eckert, P. J. Schneider, A. A. Hayday and R. M. Larson. *Jet Propulsion*, **28**, 34–9 (*Jan.*, 1958). (8 *refs.*)

.6 *Electricity and Magnetism*

(673) **Temperature consideration in solar battery development.** R. E. Halstead. *J. Appl. Phys.*, **28**, 1131 (*Oct.*, 1957). (6 *refs.*)

.7 *Cosmic Radiation*

(674) **Unexpected cosmic radiation could raise space flight problem.** *Aviation Wk.*, **68** (18), 39 (5 *May*, 1958). Notes on Explorer indications of high intensity radiation belt at heights of 1000 miles.

(675) **New knowledge of the extra-atmospheric radiation field.** H. J. Schaefer. *J. Aviation Medicine*, **29**, 492–500 (*July*, 1958). Review of cosmic radiation and auroral radiation; concludes that evidence still required before true estimate of hazard can be made. (7 *refs.*)

.8 *Other Upper Atmosphere Phenomena*

(676) **Formula for inferring atmospheric density from the motion of artificial Earth satellites.** T. E. Sterne. *Science*, **127**, 1245 (23 *May*, 1958). Gives results to within 10%. (3 *refs.*)

(677) **High atmosphere densities.** M. Nicolet. *Science*, **127**, 1317–20 (6 *June*, 1958). Proposes model of thermosphere allowing for diffusion to account for satellite observations. (18 *refs.*)

(678) **Density determinations based on the Explorer and Vanguard satellites.** I. Harris and R. Jastrow. *Science*, **128**, 420–1 (22 *Aug.*, 1958). Letter. (5 *refs.*)

(679) **Density of the upper atmosphere.** T. E. Sterne. *Science*, **128**, 420. (22 *Aug.*, 1958). Letter. (8 *refs.*)

3—CHEMISTRY AND MATERIALS

.1 *General*

(680) **Materials for ballistic rockets.** V. Parfenov. *Sovietskaya Aviatsiya* (277), 3 (24 *Nov.*, 1957). (*In Russian*). Also available in English as *Henry Brutcher Trans. No.* 4208, 9 pp., from Henry Brutcher, Altadena, Calif., U.S.A.

.2 *Chemistry*

(681) **Chemical lessons learned from Nike Ajax development.** R. B. Canright. *Industr. Engng. Chem.*, **49**, 1345–7 (*Sept.*, 1957).

(682) **The chemical industry in missile systems planning.** S. A. Johnston and H. R. Lawrence. *Industr. Engng. Chem.*, **49**, 1348 (*Sept.*, 1957).

(683) **Technology of boron hydrides.** C. J. Major. *Chem. Engng. Progr.*, **54** (3), 49–54. (*March*, 1958). Preparation, chemical and physical properties. (21 *refs.*)

.3 *Metallurgy*

(684) **New thorium alloys assure a big role for magnesium in missiles.** *Modern Metals*, **14** (3), 46–52 (*April*, 1958).

(685) **The outlook for titanium in missiles.** R. C. Durstein. *Modern Metals*, **14** (3), 64–5 (*April*, 1958).

(686) **Aluminium in rockets and missiles.** D. Fabun. *Modern Metals*, **14** (3), 30–2, 34, 36, 38, 41–2. (*April*, 1958).

(687) **From Venetian blinds to rocket tubes.** R. A. Quadt. *Modern Metals*, **14** (3), 26–8 (*April*, 1958).

(688) **Materials for rocket engines.** R. C. Kopituk. *Metal Progr.*, **73** (6), 79–84 (*June*, 1958). A variety of conditions arise in rocket engines, such as very low temperatures in some parts (due to liquid O) and very high in others. The various parts are described with notes on appropriate metals and coatings.

.4 *Refractories*

(689) **The use of refractory ceramics in rocket engines.** W. R. Sheridan. *Amer. Ceram. Soc. Bull.*, **37**, 91–4 (*Feb.*, 1958). Use in liquid propellent engines. Discusses desirable properties and materials that have been used.

.5 *Plastics*

(690) **Urethane foam protects missile instruments.** *Elect. Engng., N.Y.*, **78** (3), 282–3 (*March*, 1959). Recording instruments in nose cones of Thor and Atlas missiles are packaged in a urethane foam sphere (hard outer and soft inner shells) within a shell of re-entry material.

.6 *Miscellaneous*

(691) **Vessels for the storage and transport of liquid hydrogen.** B. W. Birmingham, E. H. Brown, C. R. Class and A. F. Schmidt. *J. Res. Nat. Bur. Stand., Wash.*, **58**, 243–53 (*May*, 1957).

(692) **Tank truck hauls liquid fluorine in 5000 lb. units cross-country.** *Aviation Wk.*, **68** (8), 63 (24 *Feb.*, 1958). Propellent transport vehicle.

(693) **Gasketing for liquid oxygen.** J. Swift and D. C. Bowersock, Jnr. *Kelvin Scale Research and Engineering*, **1** (1), 2–3 (*Sept.*, 1958). (Leaflet issued by Arthur D. Little Inc., Cambridge, Mass.). Tests of Pb, Al (dead soft), Teflon, Kel-F and asbestos-Teflon when used as gasketing for liquid oxygen between a pair of 6-in., 150-lb. raised-faced stainless steel welding neck flanges. Various surface finishes were used. Al is the least expensive with Pb a close second and having the advantage of being receptive to the cutting knife of an ordinary gasket cutter.

4—BIOLOGY AND MEDICINE

[*See also* abstract no. 675]

.4 *Anatomy and Physiology*

(694) **Physiology of launching and re-entry stress in rodents.** H. J. A. von Beckh. *U.S.A.F. Missile Development Center, TN* 58–11.

(695) **Man in space.** *Brit. Med. J.*, **2**, 1041–2 (1957).

(696) **Man in space.** H. Faust. *Naturwissenschaften*, **10**, 270 (1957). (*In German*).

(697) **The function of the vestibular sense organ and the construction of a satellite.** M. P. Lansberg. *Aeromedica Acta* (*Special edition*), 69–77 (1957).

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(852) **Inertial guidance for rocket-propelled missiles.** W. T. Russell. *Jet Propulsion*, **28**, 17–24 (*Jan.*, 1958). (14 *refs.*)

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9—RADIO AND ELECTRONICS; COMMUNICATIONS

[*See also* abstract no. 761.]

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(857) **High-temperature subassembly design.** R. B. Kieburtz. *Electronics*, **30** (5), 158–61 (1 *May*, 1957).

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(868) **Determination of radio-propagation elements due to a artificial Earth satellite.** E. Woyk-Chvojhová. *Nature*, **181**, 1195–6 (26 *April*, 1958). Letter. (1 *ref.*)

(869) **Theoretical analysis of Doppler radio signals from Earth satellites.** W. H. Guier and G. C. Weifienbach. *Nature*, **181**, 1525–6 (31 *May*, 1958). Letter.

(870) **Radio scintillations of satellite 1958 α.** O. B. Slee. *Nature*, **181**, 1611–2 (7 *June*, 1958). (2 *refs.*) Letter.

(871) **Some effects of the fine structure of the ionosphere on transmissions received from the Russian Earth satellite 1958 δ.** F. A. Kitchen and W. R. R. Joy. *Nature*,, **181**, 1759–61 (28 *June*, 1958). (7 *refs.*)

(872) **Project Vanguard Report No. 36. Minitrack Report No. 8: Time Standard.** C. A. Schroeder, E. J. Habib and W. R. Silvester. *U.S. Naval. Res. Lab. Report* NRL5227, 48 pp. (*Oct.*, 1958). (*Available as PB* 151, 169). The time standard provides a means for synchronizing the Minitrack system with WWV time signals to an accuracy of ± 1 millisecond, the 500-cps separation frequency for the receivers, means for synchronizing the operation of the digital phase meters with the standard time, and the time bases for the data records.

(873) **Electrical frontiers in space.** L. Faneuf. *Elect. Engng N.Y.*, 78 (3), 893–7 (*March*, 1959). An address by the President of Bell Aircraft Corp.; covers the Dyna-Soar programme, communication systems for space vehicles, auxiliary power units, navigation and control.

(874) **Predicting the reliability of complex electronic equipment.** A. G. Field. *Trans. Soc. Inst. Techn.*, **11** (1), 18–23 (*March*, 1959). Reliability levels required for various applications (including missiles) are compared. The reliability of complex equipment is calculated on the basis of a constant component failure rate, and the effect of ambient conditions on failure rate are discussed.

BOOK REVIEWS

Ergebnisse von Prüfstandsversuchen mit Heisswasser-Modellraketen. Von E. Schäfer und W. Michely (Mitteilungen aus dem Forschungsinstitut für Physik der Strahlantriebe e.v., Stuttgart, No. 11). 30 × 21 cm. Pp. 47, with 32 fig. August, 1957. Stuttgart: Verlag Flugtechnik/Ernst von Olnhausen. (D.M. 16.30).

The investigations with hot water rocket models (HWR) which are described were carried out in order to obtain design data for A.T.O.'s using boiling water as a propellent. The HWR comprises a pressure vessel (boiler) and a Laval nozzle, with a stopcock in between. The boiler is partly filled with hot water at slightly below saturation pressure, similar to a Ruth's steam storage vessel. An immersion heater is fitted, to achieve the same condition if cold water filling is used. On opening the stopcock, the water is expelled by the vapour pressure in the boiler and is then vaporized in the nozzle, leaving this as a high-velocity jet of saturated steam.

The time delay (boiling delay) observed in transforming boiling water to saturated steam plays an important part in the functioning of the HWR. Firstly, the boiling delay is noticed in the boiler, inasmuch as the steam pressure measured during expulsion is several atmospheres below the saturation pressure pertaining to the actual water temperature. This creates a state of superheat favourable to a quick boiling-off, which is necessary when a vessel is to empty in a short time under its own steam pressure.

Secondly, the mass flow through the nozzle is larger than expected, owing to only partial vaporization in the throat section in the very short time available. But it is shown that the unfinished vaporization can be effectively completed in the venturi if this is sufficiently long and wide. Further, the Laval nozzle proves comparatively insensitive to changes in expansion pressure ratio caused by the falling boiler pressure.

A total impulse of 88% of the theoretical value was measured with an initial boiler pressure of fifty atmospheres. It is estimated that up to 95% should be realized with a refined model. The corresponding specific impulse would be 47·5 lb. wt./lb./sec. This very low specific impulse figure would seem to be a tremendous handicap of the HWR when comparing it with an HTP steam unit (> 100 lb. wt./lb./sec.) or a conventional bi-propellent unit (> 200 lb. wt./lb./sec.).

F. C. JESSEN.

Astronautics and Space Exploration: Hearings before the Select Committee on Astronautics and Space Exploration, Eighty-fifth Congress, Second Session on H.R. 11881. 9 × 6 in. Pp. viii + 1542, illustrated. 1958. Washington: U.S. Government Printing Office ($4.50).

The significance of this publication is best illustrated by the following excerpt (p. 7):

> "*On 5 March, 1958, the House of Representatives established the Select Committee on Astronautics and Space Exploration composed of 13 members. . . . This committee is authorized and directed to conduct a thorough and complete study and investigation with respect to all aspects and problems relating to the exploration of outer space and the control, development, and use of astronautical resources, personnel, equipment, and facilities.*"

The purposed objectives of the Committee were successfully accomplished, resulting in an almost encyclopaedic report which defies adequate review. This single paper-bound volume of rather unwieldy dimensions is probably one of the largest ever printed on the American (or any government's) military and civilian space policies and programmes.

A major portion of the report consists of the testimony of America's leading authorities in Astronautics and related fields. Some of these are well known to *Journal* readers: Dr. Wernher von Braun, Dr. Walter S. Dornberger, Dr. Hubertus Strughold, Professor John Cobb Cooper, Andrew G. Haley, Dr. Joseph Kaplan and Dr. Fred L. Whipple, just to mention a few. A considerable number of those who testified presented, in addition to their verbal testimony, various technical papers, letters, charts, illustrations, etc., which were entered in the final report. A typical example, which may be of particular interest, is a 36-page "Interim Glossary of Aero-Space Terms," containing the latest additions to the astronautical vernacular.

So that the prospective reader will not be misled as to the scientific level of these hearings, it should be noted that this enquiry was conducted to aid legislators in the formulation of future astronautical policies and to examine existing policy prior to the enactment of "The National Aeronautics and Space Act of 1958." There are naturally certain technical limitations inherent in this type of proceeding. For example, the testimony is completely devoid of the rather abstruse mathematical and theoretical papers one often encounters at astronautical symposia. The replies given to questions asked by the committee are of necessity restricted to those understandable by the informed layman. This aspect of the report, however, should not detract from its importance to the specialist, particularly one interested in the application of the new aeronautical and astronautical concepts to existing organizations, laws and policies.

Since these hearings are the outcome of the American reaction to the successful Russian space projects, numerous authorities displayed a certain degree of concern during their testimony with the extent of Russian progress relative to America's. In addition, considerable emphasis was placed upon certain inadequacies of the American educational system, the problem of inter-service rivalry, the cost of space programmes and the need for more centralized leadership in future programmes. Despite these reoccurring themes, the reader is given an extremely penetrating and comprehensive view of the personalities, programmes and policies that will influence American activity in this area for many years.

This publication is an invaluable sourcebook of American legislative technique, government organization, and policy, as related to both aeronautics and astronautics. It is symbolic of Western democratic legislative processes, which are dedicated to a well-informed free people.

EDWARD D. RODGERS, Jnr.

Advances in Geophysics. Volume 4. Edited by H. E. Landsberg and J. Van Mieghem. 9 + 5¾ in. Pp. x + 456, illustrated. 1958. New York: Academic Press, Inc. ($12). London: Academic Books Ltd. (86s.).

This volume continues the excellent series reporting progress in Earth sciences, which has been appearing since 1952. It contains five well-documented review articles which not only survey past work but point out the unsolved problems and the paths for future research.

"Atmospheric Chemistry" by Christian E. Junge (pp. 1–108; 152 ref.) deals only with the chemistry of active trace substances in the troposphere. This includes natural aerosols, their size distribution, constitution and origin; trace gases (CO_2, O_3, N_2O, NO, NO_2, NH_3, SO_2, H_2S, halogens, CH_4, CO, HCHO); precipitation chemistry; and air pollution.

"Theories of the Aurora," by Joseph W. Chamberlain (pp. 109–213; 113 ref.) surveys the many hypotheses advanced to account for auroral phenomena; it is clear that none of these is completely satisfactory.

The paper of most astronautical interest is "The Effects of Meteorites upon the Earth (Including Its Inhabitants, Atmosphere, and Satellites)," by Lincoln La Paz, who is the Director of the Institute of Meteoritics, University of New Mexico (pp. 217–350; 202 ref.). After distinguishing between *meteorites* (objects of *extra*-atmospheric origin) and *tekites* (silica glasses of *intra*-atmospheric origin, which arise from the oxidation of meteorites), effects produced by the former are indicated. La Paz points out that the possibility of damage or injury from falling meteorites is definitely not one of purely academic interest, in view of the rapidly-increasing human, built-over and vehicular target areas (HTA, BTA and VTA respectively). He gives a list of injuries (human or higher animal) reported as caused by falling meteorites; it begins with the remains of a megatherium found 6 m. above a stony-iron meteorite and the incident mentioned in *Joshua*, x, 11 (both of these are rated "doubtful"), and ends with the twentieth event—injury to a woman at Sylacauga, Alabama, in November, 1954 (rated "certain"—although it is pointed out that the "meteorite did not score a direct hit on Mrs. Hodges, but rather clobbered her on the first bounce"). Assuming a pattern of growth from the world's HTA, probabilities are worked out for future hits up to 3300 A.D.—but there does not appear to be any need for life insurance companies to be unduly worried. Authenticated direct hits on buildings have naturally been more numerous, but even here the probability that at least one meteor will hit the BTA of New York City during the entire twentieth century is only 50–50. Hits in VTA's will naturally be more numerous, as this concerns space vehicles travelling outside the atmosphere. The major part of the paper is devoted to a discussion of meteoritic abundances and the problem of hyperbolic meteoritic velocities, including the relation of the frequency distribution of meteorite falls to the right ascension of the Moon at the time of fall (this provides convincing evidence for the existence of both solar system and interstellar meteorities). Dr. La Paz concludes with a survey of terrestrial crater formation by meteorites: at the time of writing craters of this type had been recognized at fourteen localities (three in U.S.A., five in Australia, two in U.S.S.R., one each in Arabia, the Sahara, Estonia and Argentina —the Chubb crater in Canada has not yet been recognized as meteoritic.

The purpose of "Smoothing and Filtering of Time Series and Space Fields," by J. Leith Holloway, Jnr., is to give the reader a better understanding of what is accomplished by the smoothing methods used by the geophysicist to remove unwanted data.

"Earth Tides," by Paul J. Melchior (pp. 391–443; 35 ref.) covers tidal theory, oceanic tides, periodic deflections of the vertical with respect to the crust and to the Earth's axis, variations in the intensity of gravity, the rôle of the geologic structure of the crust, and the effect of Earth tides on the speed of rotation of the Earth.

This volume is well worth purchasing, if only for the interesting and authoritative contribution of La Paz.

G. V. E. THOMPSON.

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